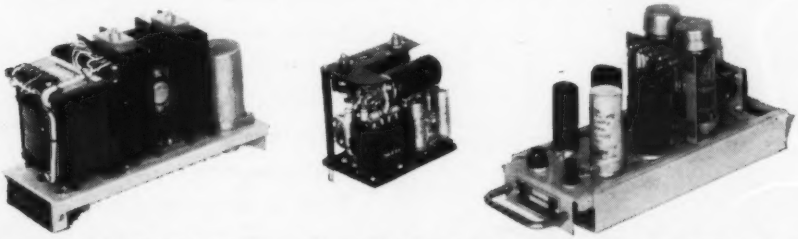
Physics.
Cole Memorial Library
OHIO STATE UNIVERSITY
OCT 27 1959
LIBRARY

INSTRUMENT Practice AUTOMATION & ELECTRONICS

Vol. 13 No 9. Published Monthly September 1959

THE SERVO MOTOR YOU REQUIRE

THE AMPLIFIER TO CONTROL IT



THE EXPERIENCE & KNOWHOW TO APPLY IT

ALL ARE AVAILABLE FROM

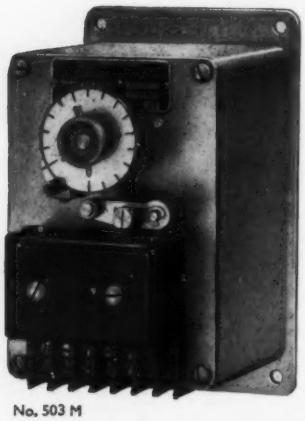
EVERSHED

Amplifiers — Power Packs — Armature Rectifier Units.
Gear Boxes — Gear Heads — Motors 0.25 to 100 watts output.
Special purpose A.C. Motors 12½ to 1000 cycles:
Synchronous Motors—General Purpose D.C. Motors.
Brushless D.C. Tacho Generators—A.C. and D.C. Generators.

Send for Publication IG.301 which gives full details.
INSTRUMENTS DIVISION, **EVERSHED & VIGNOLES LIMITED, ACTON LANE WORKS, LONDON, W4**
Telephone: Chiswick 3670 Telegrams & Cables: Megger London Telex 22583

Circle 1 for further information

Circle 2 for further information



No. 503 M

every type of movement

for scientific instruments

No. 595

Meters	POINTERS
Electric clocks	DIFFERENTIALS
Telephones	PINIONS
Time switches	SPINDLES
Recorder clocks	WORMS
Gauge movements	WHEELS
Synchronous motors	ESCAPEMENTS
Measuring instruments	COMMUTATORS
Prepayments	
Relays	

The British Sonceboz Co. Ltd.

VICTORIA ROAD - SOUTH RUISLIP - MIDDX. *Tel.*: RUISLIP 5590 & 3128

In association with

SOCIÉTÉ INDUSTRIELLE DE SONCEBOZ, S.A., SWITZERLAND

ITALY Carlo Caglioni Société Industrielle de Sonceboz, S.A., Ufficio di Milano, Via Mac. Melloni 70, Milano
U.S.A. Alina Corporation, 122 East Second Street, Mineola, L.I., N.Y.

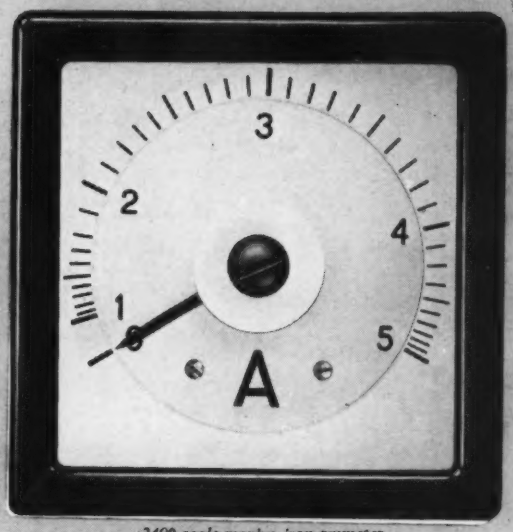
Circle 3 for further information

240° SCALE Instruments

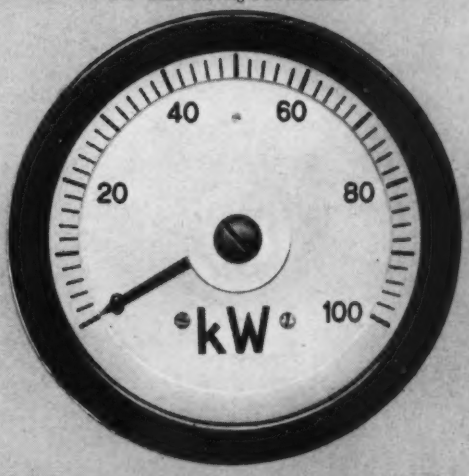
for switchboard mounting

* **Design permits 'on site' modifications or maintenance to either the moving coil or the dynamometer movement without disturbance of the original accuracy.**

* **Models are available for direct wire remote indication.**



240° scale moving iron ammeter



240° scale dynamometer wattmeter

Instruments in this range are of an advanced design incorporating many features including platform type scales. The movements are robust in construction and have a high torque/weight ratio. Low burden types are available for miniaturised control panel installations, with associated interposing voltage- and current-transformers.

Specifications:

These Instruments comply with B.S.89-1954 Industrial Grade and other International Specifications.

Literature available on request to:
The ENGLISH ELECTRIC Company Ltd.,
Instrument Department, Stafford

'ENGLISH ELECTRIC'

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

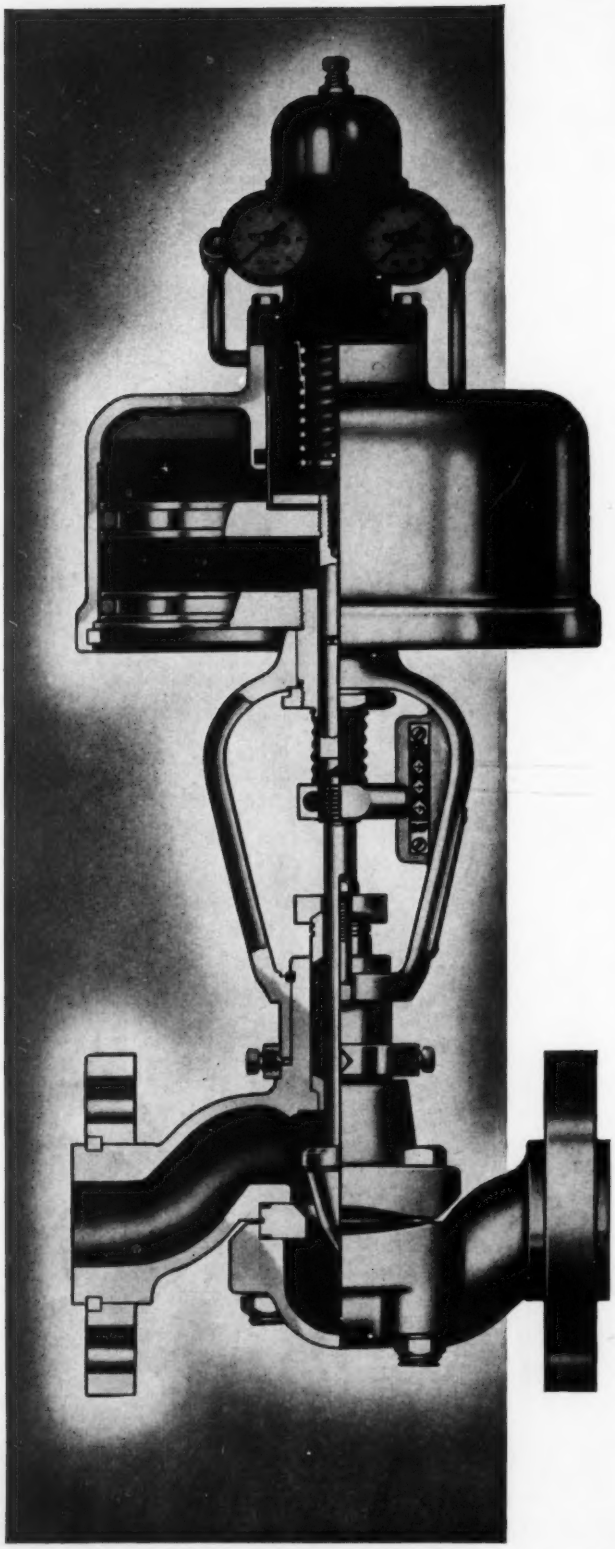
Meter, Relay and Instrument Division, Stafford

INS. 47

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

Circle 4 for further information

THE ANSWER TO CONTROL PROBLEMS



AUDCO ANNIN VALVES

DOMOTOR CONTROL, CYLINDER AND HANDWHEEL OPERATED IN SIZES ½" TO 10"

Audco Annin Valves are recognised by Control Engineers and Valve Designers as the outstanding valve development of the past 25 years for the control of hot, cold, erosive, corrosive or viscous services.

THE DOMOTOR supersedes the conventional diaphragm and spring type servomotor. A power piston with integral positioner, the Domotor is capable of :—

- Positioning the valve with an accuracy measured in thousandths of an inch, regardless of varying stem forces.
- Longer stroke allows improved trim design.
- Equal power available throughout the stroke.
- Supplied with side-mounted-handwheel if required.
- Will open or close on main air or 3-15 psi instrument air failure. Available to 'open' or 'close' on increasing signal pressure. The Domotor can be readily converted to either application on site.

AUDCO ANNIN Valves

Audco Annin Control Valves are available up to 2500 ASA rating.

AUDLEY ENGINEERING COMPANY LIMITED, NEWPORT, SHROPSHIRE

Circle 5 for further information

DATA LOGGING AND DIGITAL DISPLAY

ANALOGUE INPUTS

TEMPERATURES
RESISTANCES
DIMENSIONS
PRESSURES
VOLTAGES
WEIGHTS

UP TO 600 REMOTE DISPLAYS
1—4 DIGITS
£10 PER DECADE
0·05% ACCURACY
IN-LINE PRINTER DRIVE
DIGITAL STORAGE

DIGITAL OUTPUTS

This versatile Data Display System has applications in fields where accurate measurement and display of digital information is required, as in ground radar systems, nuclear power plants and chemical processes, etc.

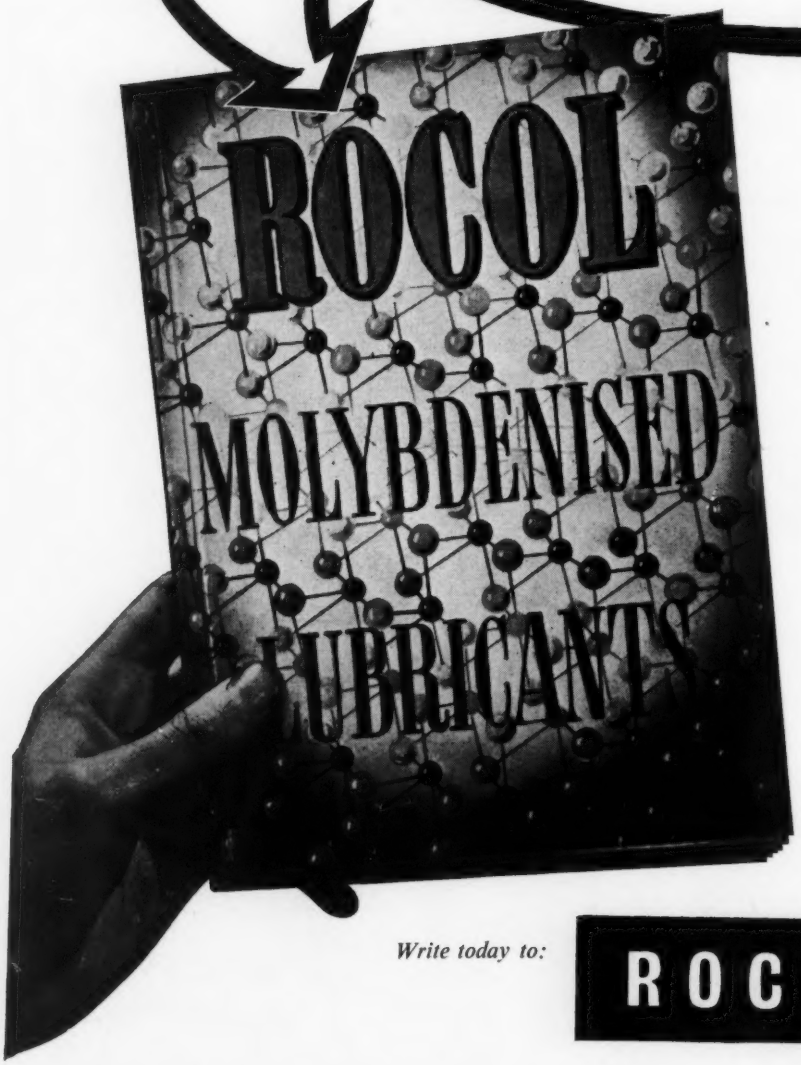
It accepts inputs from thermocouples, pressure pick-ups, flowmeters and other transducers, displaying this information in digital form on any number of remotely situated displays. Each display has its own digital storage unit, which is capable of driving an output printer or tape punch.

BLACKBURN ELECTRONICS LIMITED
BROUGH • YORKSHIRE **TELEPHONE BROUGH 121**

BE

Circle 6 for further information

Read all about Molybdenised Lubricants in this FREE BOOK



The most comprehensive treatise on Molybdenum Disulphide Lubrication yet published, this book can be of great value to **you.**

Write today to:

ROCOL LTD

GENERAL BUILDINGS, ALDWYCH, LONDON, W.C.2 *Telephone: HOL 1985*
ROCOL HOUSE, SWILLINGTON, NR. LEEDS *Telephone: Garforth 2261/2*

n.d.h. 3287/A

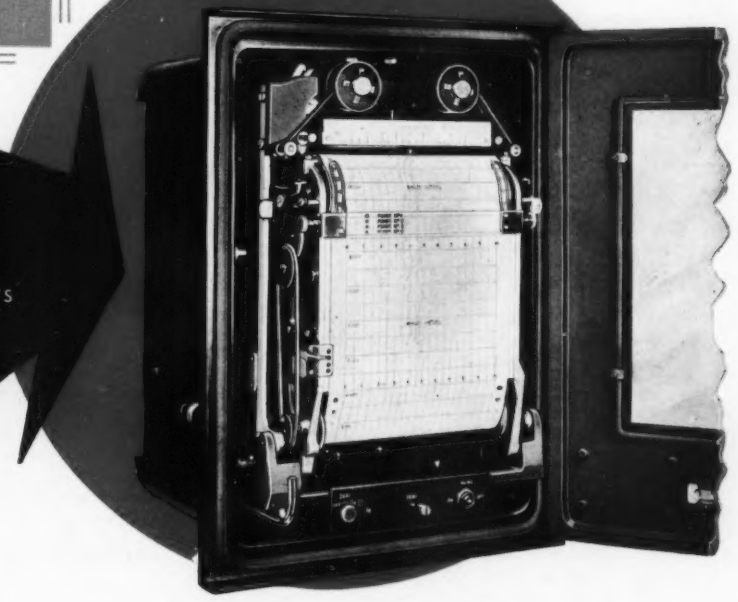
OBTAIN *Automatic* MULTI-POINT RECORDING AND *Accuracy* WITH THE *Bailey* ELECTRONIC SELF-BALANCING STRIP CHART RECORDER

FOUR-POINT THERMO-COUPLE VERSION

£164

OUTPUT

MULTI-POINT MULTI-COLOUR RECORD ON LONG LIFE CHART



INPUT

THERMO-COUPLES
RESISTANCE ELEMENTS
OR ANY SUITABLE
CURRENT OR
VOLTAGE
SOURCE

SPECIAL FEATURES

High accuracy and speed response. ●
Provision for 4 independent records—each colour coded differently. ●
4 chopper-bar operations every 30 seconds. ●
Long-life chart and ink ribbon. ●
Fully sealed oil-immersed servo motor and slide wire. ●
Calibration unaffected by valve replacement. ●
Alarm Contacts available. ●

For Instruments using Thermo-couple Inputs

Transistorized d.c./a.c. converter—no moving parts ●
Neon stabilized reference voltage—eliminates the need for dry batteries. ●
Automatic cold junction temperature compensation. ●

BAILEY METERS

Send for fully illustrated Product Specification E(E12-12)

BAILEY METERS & CONTROLS LTD.

PURLEY WAY · CROYDON · SURREY *Telephone: CROydon 4191*

INSTRUMENTS AND CONTROL SYSTEMS FOR THE POWER AND PROCESS INDUSTRIES

Circle 8 for further information

Size: 12¼″ x 9½″ x 6⅞″
Weight: 14 lbs

RESOLIA

FOSTER Portable Potentiometer

AND PYROMETER TESTER

Developed from the long and successful line of Foster Portable Potentiometers now comes Model 3155, which retains all the outstanding features of the previous models despite reduction in size and weight by over 50%. Main scale remains 14″ long, cold-junction scale 6″ long.
Still completely self-contained, incorporating sensitive null deflection galvanometer, standard cell, standardising switch and rheostat and long life dry cell. Instructions for use and relative diagrams are printed on a metal plate permanently fitted in the lid. Built-in optional extra features are :—
Electrical Resistance Measurement facilities, Potential Divider with coarse and fine adjustment, and long life dry cell. The strong case of aluminium alloy is finished with a hard-wearing polychromatic Aleutian grey paint.

STANDARD RANGES

0 — 20 mV. single range
0 — 60 mV. single range
0 — 20 mV. and 0 — 60 mV. double range
0 — 20 mV. and one temperature range
0 — 60 mV. and one temperature range
0 — 20 mV. and 0 — 60 mV. and three temperature ranges
Temperature scales may be in °C or °F
Special ranges to order
Resistance Measurement :
0 — 20 ohms and 0 — 200 ohms reading on 20 mV. scale
0 — 60 ohms and 0 — 600 ohms reading on 60 mV. scale

For full technical details write to :

FOSTER INSTRUMENT CO. LTD., LETCHWORTH, HERTS Telephone Letchworth 994/5/6

Members of S.I.M.A. & B.I.M.C.A.M.

Circle 9 for further information

Relays that latch magnetically and hold without power

We call them REMANENT RELAYS. They make obsolete the use of hold-on coils and contacts and are eminently suitable for DIGIT STORE and REMOTE CONTROL applications. Fitted with cores having a high retentivity rating, they latch-up on receipt of a signal and remain so without power, until the core flux is cancelled.

Two versions—types 3,000 and 600. Fitted with a variety of coil windings and contact assemblies.
We shall be glad to give you full specification details.

TMC

REMANENT RELAYS

TELEPHONE MANUFACTURING COMPANY LIMITED
Relay Division
Hollingsworth Works
London SE21
Telephone: GIPsy Hill 2211

Circle 10 for further information

Stabilized
POWER PACKS

PP1 FOR THERMIONIC VALVES

£150 NETT IN U.K.

Leaflet C60

- High-power 0-600 volts stabilized 300 mA max.
- L.T. supplies stabilized — two independent outputs at 6·3 volts 4 amps.
- H.T. source resistance less than 0·1 ohm at d.c. and less than 0·5 ohm up to 30 kc/s.
- H.T. source resistance may be varied up to a maximum of 40 ohms.
- Mains ripple of up to 6 volts can be superimposed on H.T. line.
- Overload protection of H.T. line by resettable cut-out.

Advance COMPONENTS LIMITED

INSTRUMENTS DIVISION

ROEBUCK ROAD • HAINAULT • ILFORD • ESSEX • TELEPHONE : HAINAULT 4444

Circle 11 for further information

by Advance

Two new stabilized power packs with outstanding features for the development engineer.

The Type PP.1 has the unique features of stabilized L.T. voltages, variable H.T. source resistance, and mains ripple injection on the H.T. line.

The Type PP.3 is fully transistorized and provides simultaneous d.c. voltages of either polarity, and is fully protected against accidental short-circuit.

PP3 FOR TRANSISTORS

£110 NETT IN U.K.

Leaflet C62

- **Two independent variable d.c. supplies 0-30 volts 1 amp.**
- **Positive and negative supplies provided simultaneously.**
- **Up to 60 volts d.c. by series connection.**
- **Fully protected against short-circuits.**
- **Ripple less than 1 mV peak-to-peak.**
- **Both voltage and current monitored simultaneously.**

We shall be pleased to arrange for our Area Sales Engineer to demonstrate these models to you.

GD81.

Circle 12 for further information

For protection
against flame-failure

FLAME-FAILURE & IGNITION CONTROLLERS TYPES 700 & 701

For gas or oil-fired systems

Completely reliable

Extremely versatile

These high-quality Controllers eliminate the dangers arising from flame-failure, and are effective in almost all types of gas or oil-fired furnaces. They employ an infra-red-sensitive photo-cell to 'see' the flame in furnaces, which discriminates between flame and furnace-radiation. The photo-cell reacts instantly to flame-failure and, should this occur, the fuel supply is immediately shut off by an electronic control unit.

Two Controllers are available. The Type 700 is semi-automatic (with provision for automatic purge cycle) and the Type 701 is a fully-automatic relight unit

Other Controllers operating on flame-conductivity or flame-rectification, and complete installations, are also available.

Further details gladly supplied on request.

ETHER LIMITED

ENQUIRIES, SALES AND SERVICE:

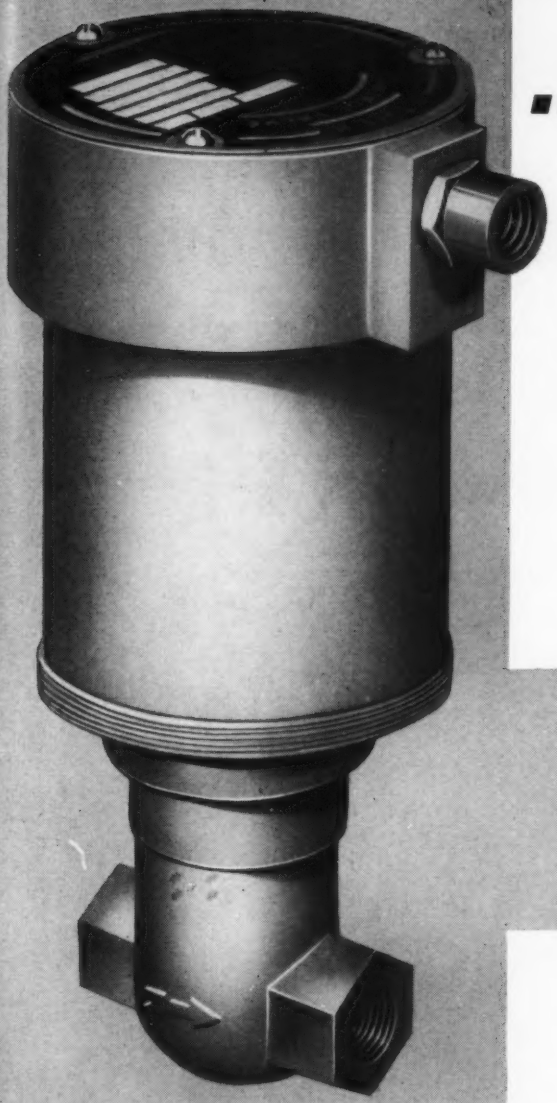
CAXTON WAY, STEVENAGE, HERTS.: STEVENAGE 2110-7

TYBURN ROAD, ERDINGTON, BIRMINGHAM, 24: EAST 0276-8

Representatives throughout the U.K.

Agents in all principal countries

Circle 12 for further information



*

Illustrated is one of the HPO series of valves designed for high-viscosity liquids

*

...and to complete your installation

SOLENOID VALVES

One of a range of highly-efficient solenoid valves, the HPO is designed for applications where oil viscosity is likely to exceed 200 seconds Redwood No. 1. A powerful solenoid ensures a maximum lift under adverse conditions of viscosity.
Non-standard versions, for operation with other high-viscosity liquids, or at specially high working-temperatures, are available to order. A lever-operated or press-button-operated hand-reset feature can also be provided.

Other valves are available for use with town gas, bottled gases, air and many fluids.

COMBUSTION SAFEGUARD AND SOLENOID VALVE DIVISION

ETHER LIMITED

Circle 13 for further information

25 *transformers for*

BRIDGE RECTIFIER CIRCUITS*

are included

amongst the 700

standard transformers and

chokes listed, priced and

fully described in the

NEW

Gardners loose leaf catalogue

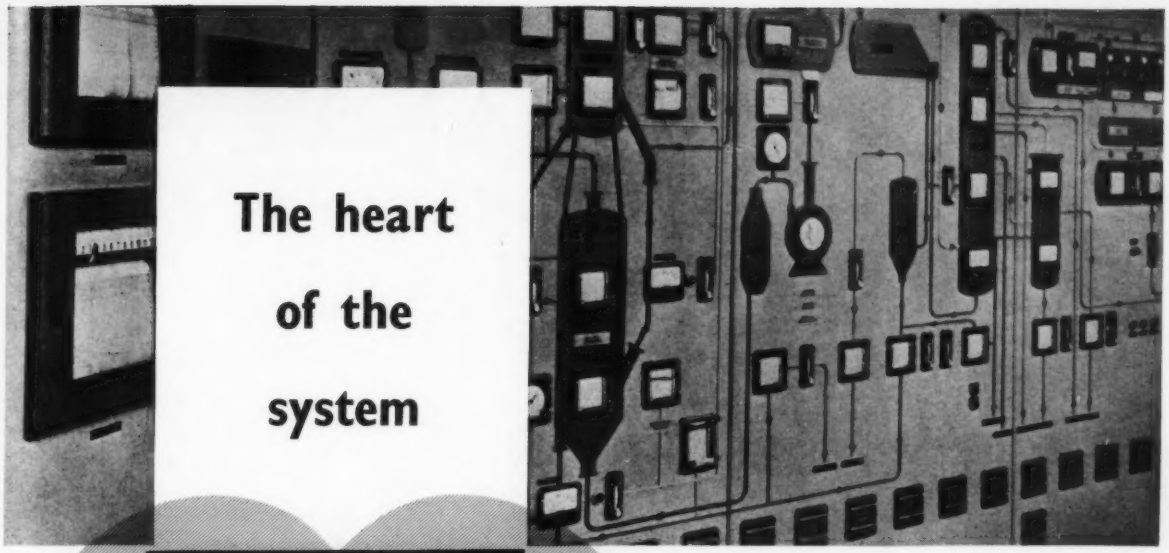
* *with Westinghouse and S.T.C. rectifiers; outputs ranging from 100v @ 60mA to 31v @ 11.2A*

Every copy of the catalogue sent out is numbered and registered in the name of the holder to ensure it is regularly brought up to date by the supply of amendment sheets covering every addition to Gardners standard ranges.

Please write for catalogue to

GARDNERS RADIO LTD., SOMERFORD, CHRISTCHURCH · *tel. 1734*

Circle 14 for further information



The heart of the system

For measuring flow, pressure or displacement there is no sensing device like the differential transformer used in Autronic transmitters. Simple, robust, with no moving parts or delicate components to be affected by shock or corrosion in hazardous positions, it provides exact electrical gauging of small mechanical movements with infinite resolution and high performance, it has low impedance with linear signal output, and it can add, subtract or average signals . . .

. . . just one example of the outstanding advantages of the Swartwout Autronic Control systems

Swartwout *Autronic* CONTROL SYSTEM

THE SWARTWOUT COMPANY LIMITED

CENTURY WORKS, LEWISHAM, S.E.13

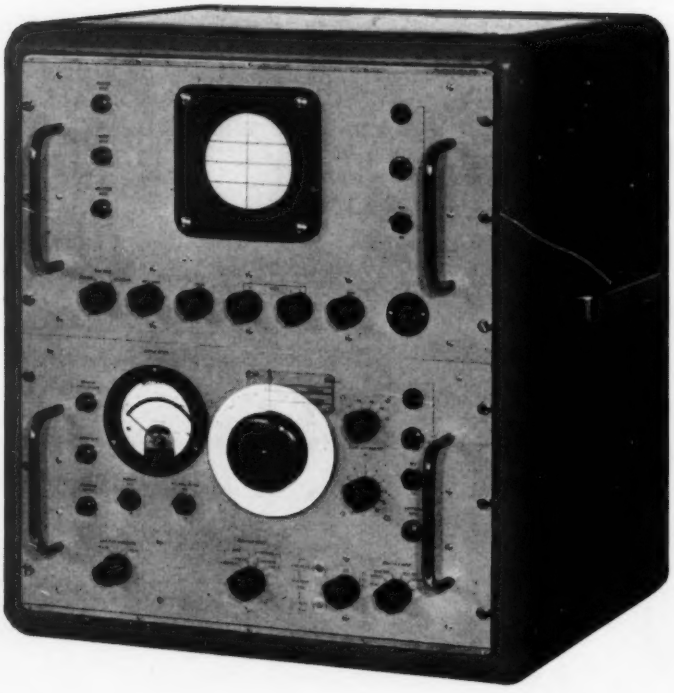
A MEMBER OF THE ELLIOTT-AUTOMATION GROUP

EA

Circle 15 for further information

SPECTRUM ANALYSIS

SPECTRUM ANALYSER TYPE 190



The Spectrum Analyser Type 190 is employed to analyse the spectrum of a signal in the frequency range 1-90 kc/s. Characteristic features of this instrument are its high resolution, with a minimum bandwidth of 70 c/s with the response more than 50 dB down at 150 c/s removed from the centre frequency, high threshold sensitivity which is of the order of a fraction of a microvolt, and panoramic displays.

After amplification, the signal is fed to a broadband mixer supplied with reference signal from a heterodyne oscillator sweeping either manually or automatically through the range 101-190 kc/s. The lower sideband of the signal is accepted by a filter centred on 100 kc/s and having a fixed bandwidth of either 70 c/s or 1 kc/s.

Alternative panoramic spectrum display or accurate indication of signal power on a thermocouple milliammeter is provided. Input signal components from 0·1 volt to less than 1 microvolt rms in a 70 c/s band can be measured with an accuracy of ±1 dB.

JAMES SCOTT & CO. (Electrical Engineers) LTD.

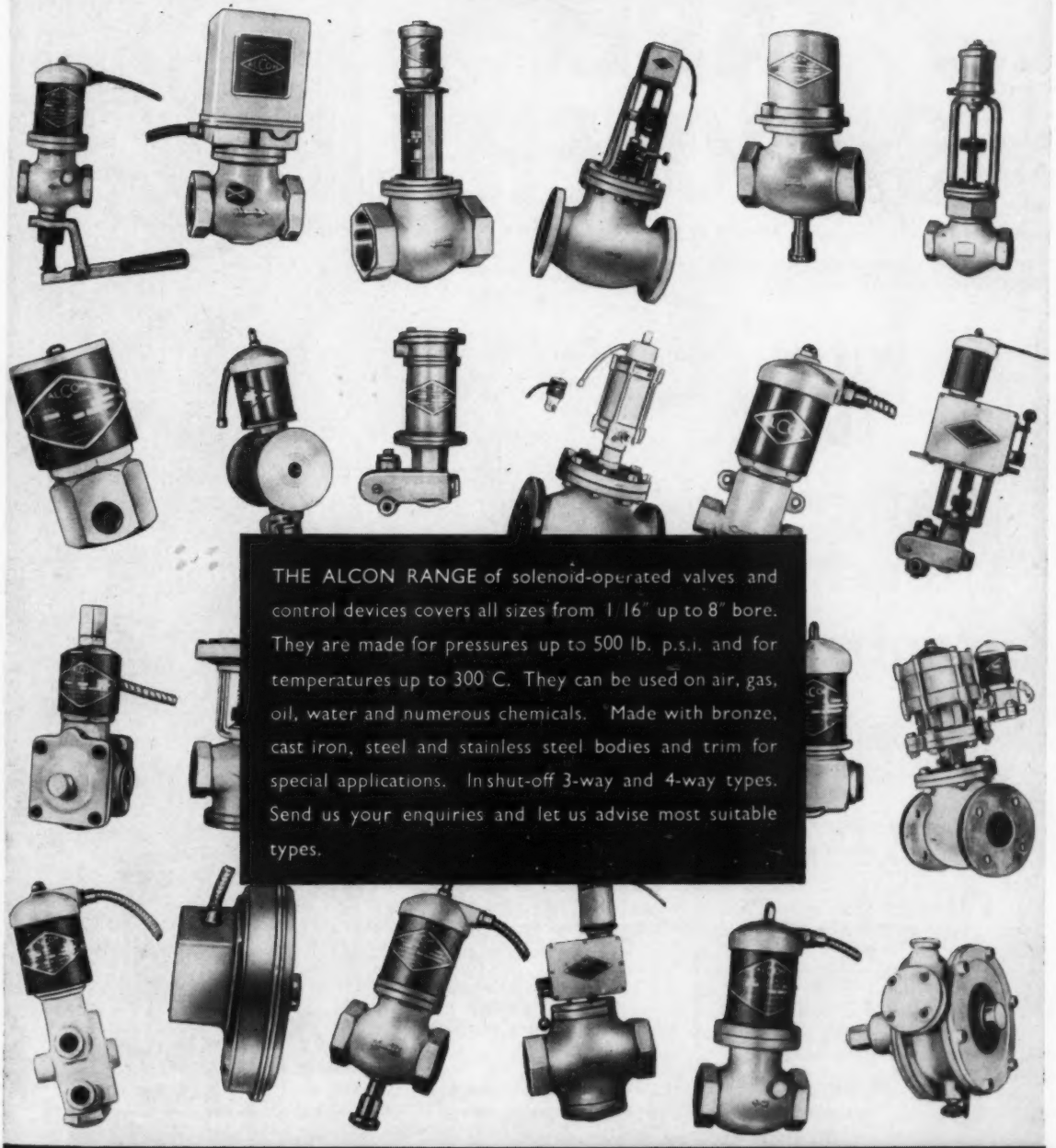
Manufacturing & Electronics Division

CARNTYNE INDUSTRIAL ESTATE, GLASGOW, E.2

Telephone: SHETTLESTON 4206-9

SOLENOID VALVES & CONTROL DEVICES

ALCON



THE ALCON RANGE of solenoid-operated valves and control devices covers all sizes from 1/16" up to 8" bore. They are made for pressures up to 500 lb. p.s.i. and for temperatures up to 300° C. They can be used on air, gas, oil, water and numerous chemicals. Made with bronze, cast iron, steel and stainless steel bodies and trim for special applications. In shut-off 3-way and 4-way types. Send us your enquiries and let us advise most suitable types.

ALEXANDER CONTROLS LTD., Reddicap Hill, Sutton Coldfield, Warwickshire.

Telephone: SUTton Coldfield 5227-8-9

MEMBER OF THE CONCENTRIC GROUP OF COMPANIES

Circle 17 for further information

The Seal in-a-Second!

ELECTRIC TAPE SHOOTER

---with the 'feather touch' control

- SAVES FATIGUE IN PACKING
- SAVES TAPE BY PRE-SET LENGTHS
- AUTOMATIC MOISTENING CONTROL
- MORE PARCELS PACKED PER DAY
- DESIGNED FOR RAPID SEALING OF HEAVY BALES, CARTONS AND CONTAINERS

★ THE HIGH SPEED PRESS - BUTTON GUMSTRIP (REGD.) SEALING TAPE SHOOTER

- Send for the illustrated leaflet or ask for a free demonstration in your packing department

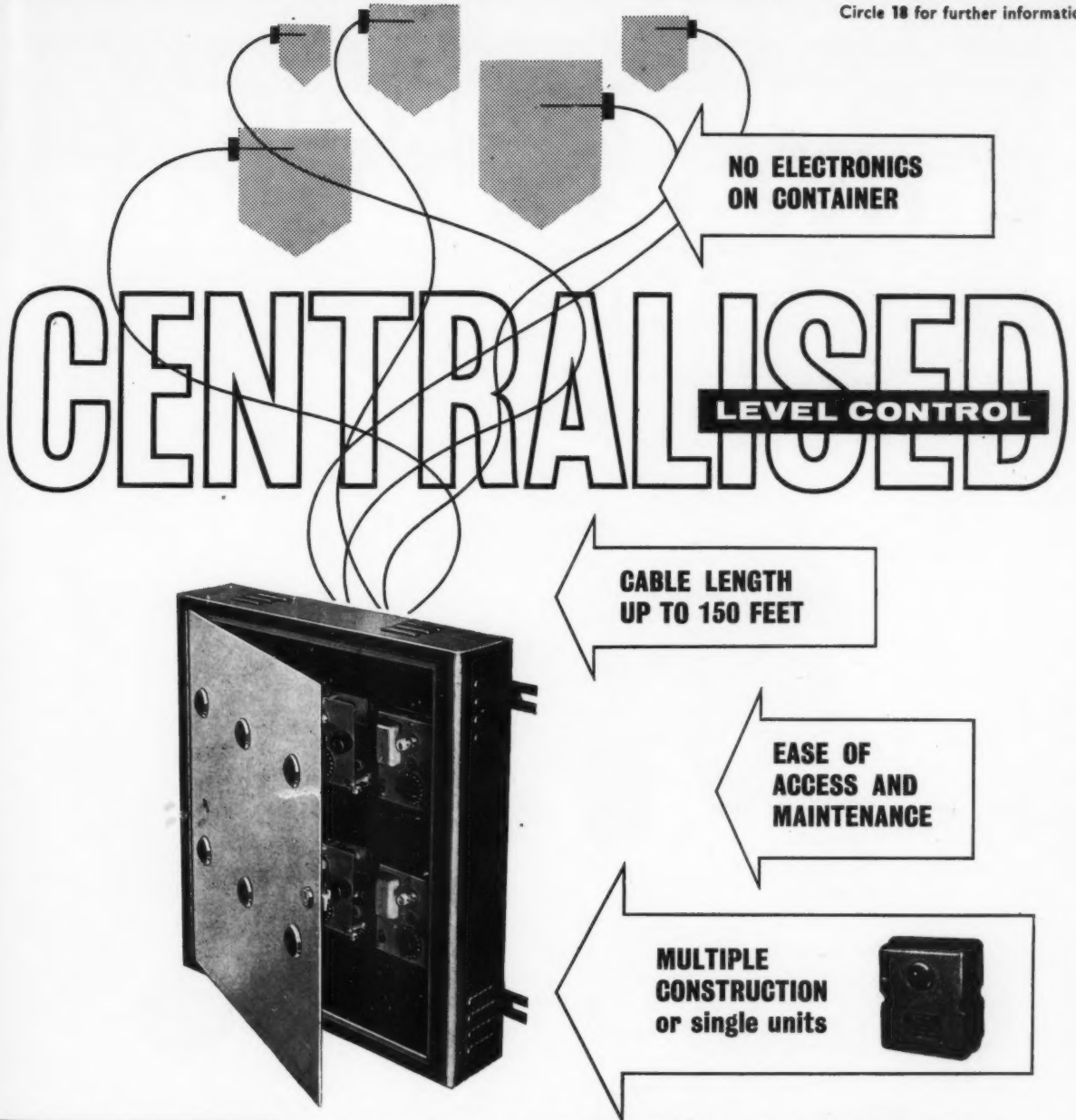
Details from:

SAMUEL JONES & CO. LTD.

NEW BRIDGE STREET, LONDON, EC4. *Tel:* FLEet Street 6500

BUTTERFLY BRAND

Circle 18 for further information



Fielden
TEKTOR MINOR

* **The instrument consists of a probe which is installed on the container and an electronic unit which can be conveniently situated at ground level for ease of access and maintenance.**
* **The Interconnecting Coaxial Cable is supplied with the instrument. No other cables are required from probe to unit and installation costs are therefore reduced to a minimum.**
* **Multiple Construction of the electronic units provides centralised or grouped indication as required.**

The first TEKTOR level Controller was introduced by Fielden Electronics Ltd. in 1949. This was the first level controller to operate on the capacitance principle. Since then many thousands have been installed throughout the world for controlling the level and flow of solids and liquids in every known industry.

Ten years experience is built into every Tektor and for this reason is acknowledged the best, most reliable and successful electronic level controller in the world.

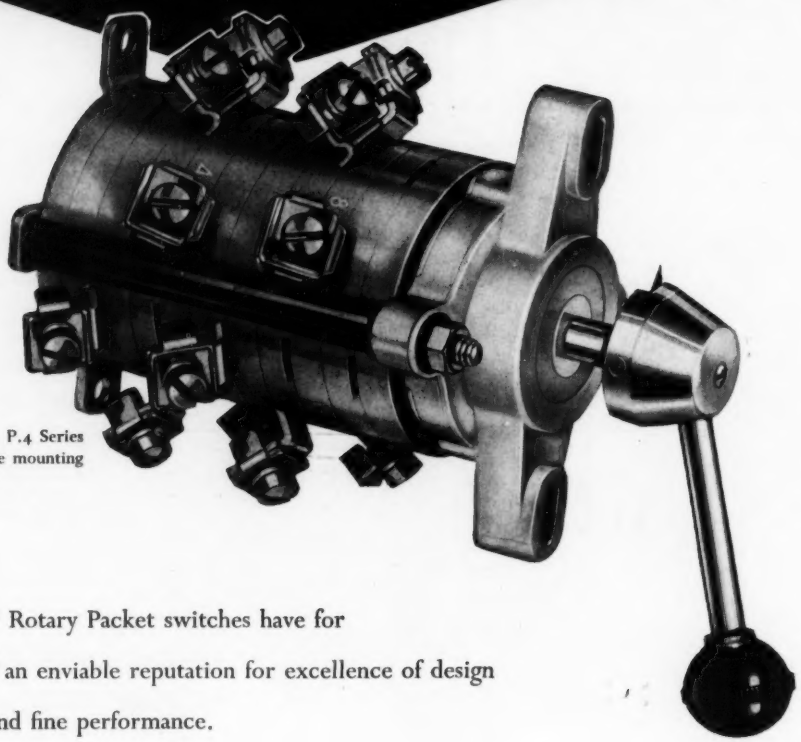
Fielden

Indicating Recording Control

FIELDEN ELECTRONICS LTD · WYTHENSHAWE · MANCHESTER Phone: Wythenshawe 3251 (5 lines) Grams: 'Humidity Manchester'
ALSO AUSTRALIA · ITALY · CANADA *Branch Offices:* LONDON · WALSALL · STOCKTON-ON-TEES · EDINBURGH

Circle 19 for further information

MULTI-CIRCUIT ROTARY PACKET SWITCHES



The illustration shows our P.4 Series arranged for panel and base mounting with machine type handle.

ARROW Rotary Packet switches have for many years enjoyed an enviable reputation for excellence of design and fine performance.

Considerable saving in cost can be effected by the simultaneous switching of various circuits using ARROW Rotary switches.

Write TODAY for a copy of LIST R.P.2 describing our P.4 Series illustrated here.

P.4 SERIES

Maximum Non-Reactive Ratings
30/35 Amps 250 v AC/DC
20/30 Amps 440 v AC/DC
12.5/25 Amps 600 v AC/DC

ARROW

ARROW ELECTRIC SWITCHES LTD

HANGER LANE · LONDON W.5

A25

The **L.F. SIGNAL GENERATOR . . .**

Type **SG.81.**

Five features of this outstanding instrument

1...Wide frequency range
15 c/s to 200 kc/s

2...Output impedance
600 ohms **balanced**
600 ohms unbalanced
300 ohms unbalanced

3...Attenuator—**balanced or unbalanced**—range
70 dB in 1 dB steps

4...Maximum output
1 watt into 600 ohms

5...Output calibrated in
volts and dB

—in brief
Audio Signal Generation at its best!

by **Advance** *– to be sure!*

NETT PRICE IN U.K.
£85

The "Advance" type SG.81 is a wide range, low frequency, Signal Generator incorporating an excellent attenuator that can be used in the balanced or unbalanced condition and provides outstanding facilities to the audio engineer.

We should be pleased to send a copy of our Leaflet C52 to you, or arrange a personal demonstration, at your request.

Advance COMPONENTS LIMITED
INSTRUMENTS DIVISION
ROEBUCK ROAD • HAINAULT • ILFORD • ESSEX TELEPHONE : HAINAULT 4444

GD76

Circle 21 for further information

DENIS FERRANTI

Instrumentation **Encapsulation**

Waveguides **Springs**

Panels **Meters**

Electronic & Electrical Test Equipment

Experimental and prototype instruments designed and built to any specification

DENIS FERRANTI METERS LIMITED

RESEARCH AND DEVELOPMENT DIVISION: LLANGEFNI, ANGLESEY, N. WALES. Tel. Llangefni 2152

METER DIVISION: BANGOR, NORTH WALES. Telephone Bangor 3232

One of the Denis Ferranti Group of Companies

AVO INSTRUMENTATION

D.C. Amplifiers

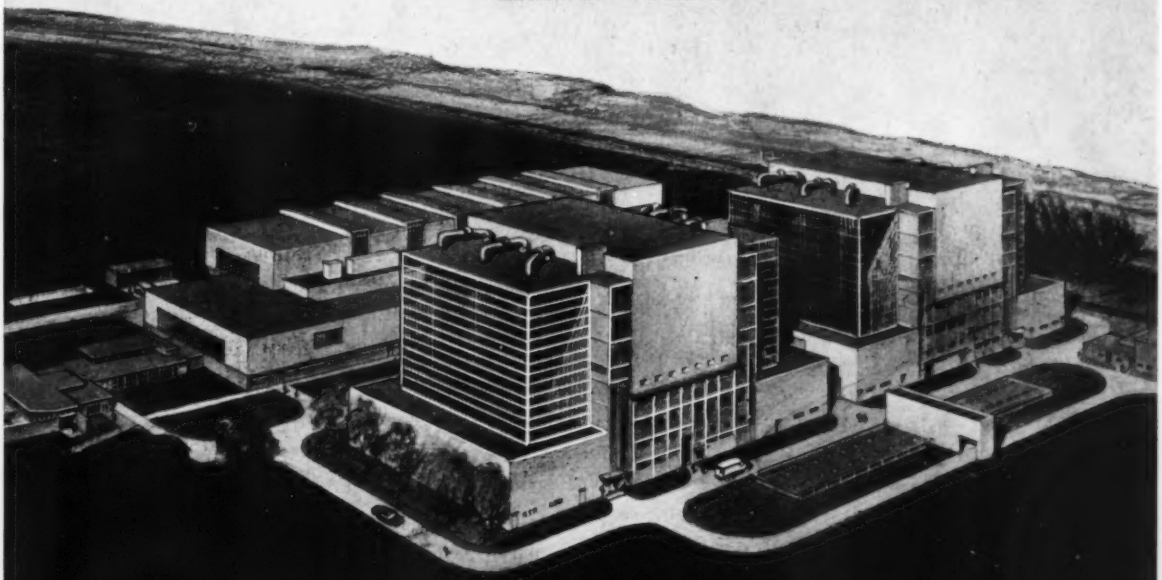
Radiation Monitors

Valve Voltmeters

Multi-range Testmeters

Valve Testers

and other electronic and nucleonic instruments.



BRADWELL NUCLEAR POWER STATION
now under construction for the
Central Electricity Generating Board.

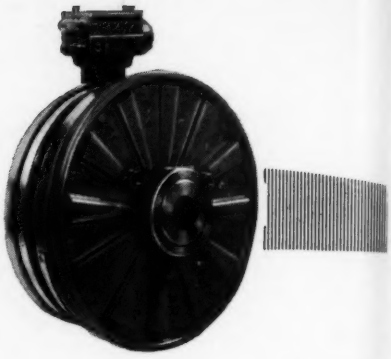
AVO LTD · AVOCET HOUSE · 92-96 VAUXHALL BRIDGE ROAD · LONDON · S.W.1

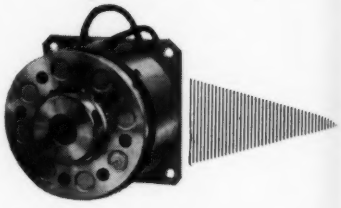
Telephone: VICtoria 3404 (12 lines) *Cables: Avocet, Sowest, London*

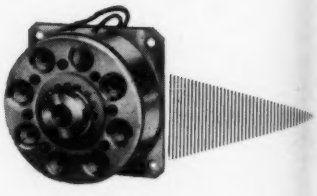
— manufacturers of Electronic Instruments since 1923

Illustration by courtesy of the designers and constructors, The Nuclear Power Plant Co., Ltd.

Circle 23 for further information







. . . for those demanding the BEST in machine control

Warner Electric Brakes & Clutches are stepping up production, shrinking costs, reducing operator fatigue and saving time.

They give lightning-fast, yet smooth cushioned stops and starts; cycle, reverse and index at the touch of a button and are remarkably simple and foolproof in use. Operation is positive and easily controlled to produce the exact torque required.

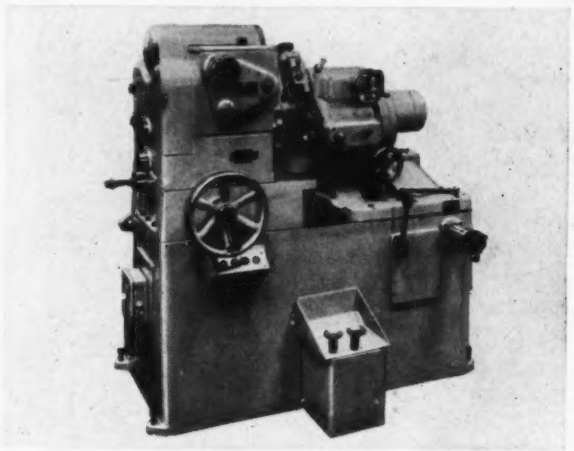
Warner units occupy the minimum of shaft length, can be fitted to existing machines and enable new machines to be built smaller, faster and easier to operate. Automatic take-up for wear completely eliminates the need for adjustment.

Our Application Engineering Division is ready to advise at the design stage of new developments or on the conversion of existing machinery. Take action NOW.

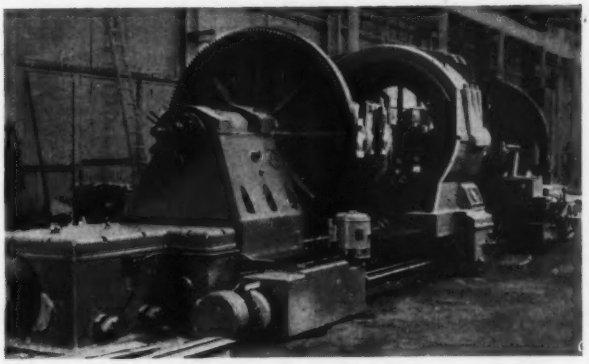
THE BRAKES AND CLUTCHES THAT STOP AT NOTHING

Circle 23 for further information

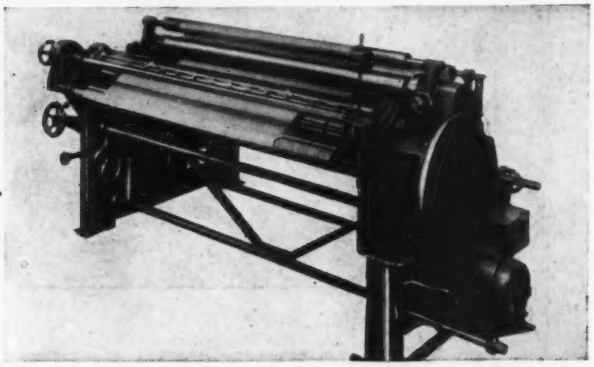
The more exacting the operation the more the need for WARNER ELECTRIC BRAKES & CLUTCHES



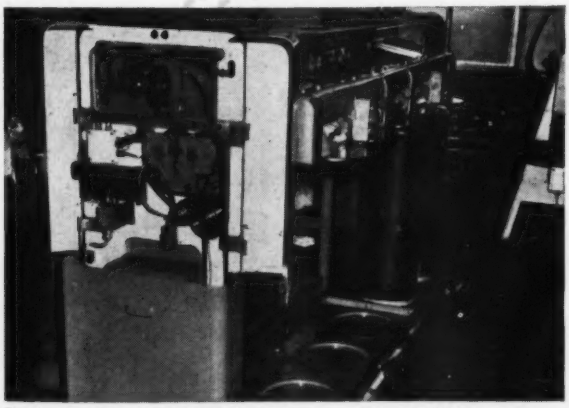
This Harry F. Atkins two spindle automatic Cam Milling Machine incorporates Warner S.F. 250 clutches to actuate an indexing drum mounted with two cutters which must be presented successively to the work and precisely positioned.
The Elgar Machine Co. Ltd. of London.



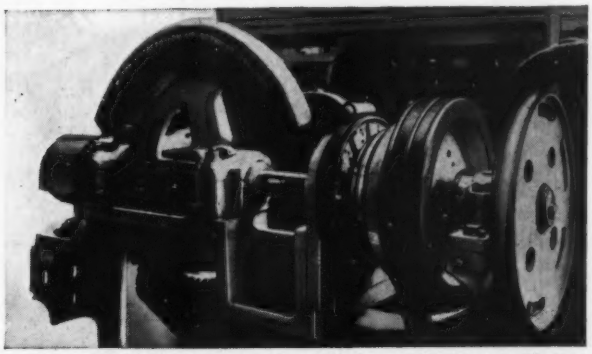
The longitudinal traverse feed of this lathe, one of the largest in the world, is controlled by a 1525 Clutch Coupling which allows remote control of the saddle with instant emergency disengagement. *Harold Butler Ltd. Manchester.*



Toilet Roll Rolling and Slitting Machine. Warner 825 Clutch fitted to main drive gives ideal slow smooth starting characteristics for the operations involved.
T. H. Dixon & Co. Ltd. of Letchworth.



Bi-coil and draw frame on textile equipment incorporating two S.F. 400 Warner Clutches.
Tweedales & Smalley Ltd. Rochdale.



A Warner 1000 Clutch in the main drive of this heavy matting loom provides pre-positioned stopping and rapid starting with safety factors hitherto unknown for this class of loom.
Wilson & Longbottom Ltd. of Barnsley.

Warner Electric Brakes & Clutches are manufactured in Great Britain under licence by:—

WESTOOL LIMITED

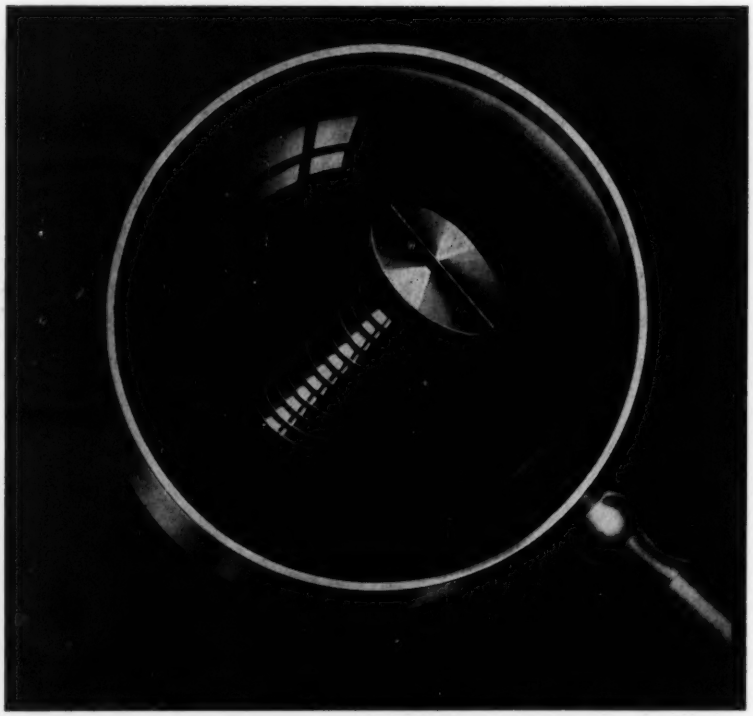
ST. HELEN'S AUCKLAND, CO. DURHAM
Phone: West Auckland 551/5. Grams: Solenoid, West Auckland
Birmingham Office: 7 Newhall Street, Birmingham 3. Phone: Central 3901

Westool also make: A.C. & D.C. Solenoids, Transformers, Coils, Coil Winding Machines, Air Conditioners, etc. and are Sole Selling Agents for the Relays, Sensing Devices and Micro-Components manufactured by A. P. Besson and Partner Ltd.

TIB. 107

TO GIVE YOU SUPER-EFFICIENT MACHINE OPERATION

Circle 24 for further information



FOR QUALITY SCREWS AND PRECISION PARTS IN STAINLESS STEEL, STEEL AND BRASS

A.I.D. AND A.R.B. APPROVED UNDERTAKING

May we send you our Catalogue?

PREMIER SCREW & REPETITION CO. LTD.
WOODGATE, LEICESTER. Telephone 25691-5

Circle 25 for further information

Another New 'TRANSITROL'!

TYPE 995

CONTINUOUSLY-ACTING PROPORTIONAL TEMPERATURE-CONTROLLER with manual reset

* ***Long-term reliability*** * ***High accuracy***
* ***Precision control*** * ***Low maintenance***
* ***7-in. indicating scale***

This new ETHER TRANSITROL Type 995 Controller operates in conjunction with a proportioning valve. It offers continuously-acting proportional control, to very close accuracy, on gas or oil-firing applications and maintains steam at a constant pressure under varying loads.

Proportional control is also available with the ETHER TRANSITROL Programme Temperature-Controller which indicates and controls temperature to a pre-determined time programme.

ENQUIRIES, SALES & SERVICE:
Tyburn Road, Erdington, Birmingham, 24 East 0276-8
Caxton Way, Stevenage, Herts. Stevenage 2110-7

Representatives throughout the U.K.
Agents in all principal countries

ETHER LIMITED

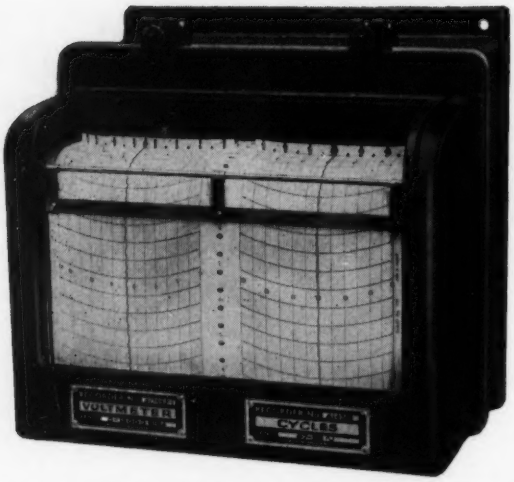
TEMPERATURE & PROCESS CONTROL EQUIPMENT FOR ALL INDUSTRIES

Circle 26 for further information

NALDERS

GRAPHIC RECORDING INSTRUMENTS

- WATTMETERS
- AMMETERS
- VOLTMETERS
- FREQUENCY METERS
- POWER FACTOR METERS



DOUBLE TYPE SWITCHBOARD PATTERN

STANDARD TYPE SWITCHBOARD PATTERN

TWO OUTSTANDING FEATURES

1 ACCESSIBILITY—easy recharting.

2 IMPROVED DRIVING MECHANISM—very accurate timing.

CHART SPEEDS

Standard speed—1 inch per hour
i.e. 65 foot roll per month.

Change gear wheels are made for multi-speed charts
Clocks are hand wound or synchronous motors.

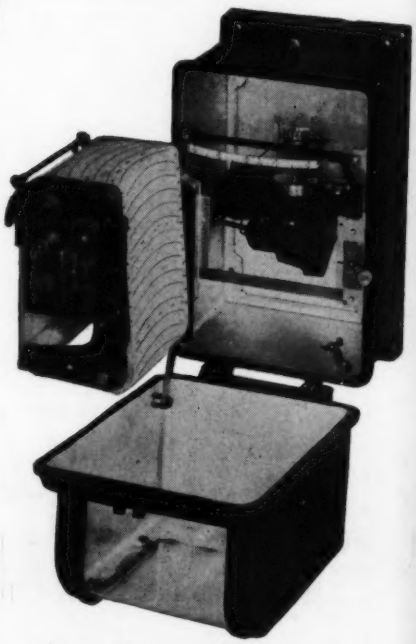
We also make PORTABLE RECORDERS

ALL are made to
NALDERS STANDARD of QUALITY
and the current
BRITISH STANDARD of ACCURACY

OTHER PRODUCTS INCLUDE

Vectormeters, Protective Relays, 'Bijou' Circuit Breakers, Flameproof Instruments, Automatic Earth Proving Supply Switches.

An illustrated pamphlet, giving complete details about these instruments, will gladly be sent on request. Please quote Ref. J6C.



NALDER BROS & THOMPSON LTD.,

Dalston Lane Works, London, E.8

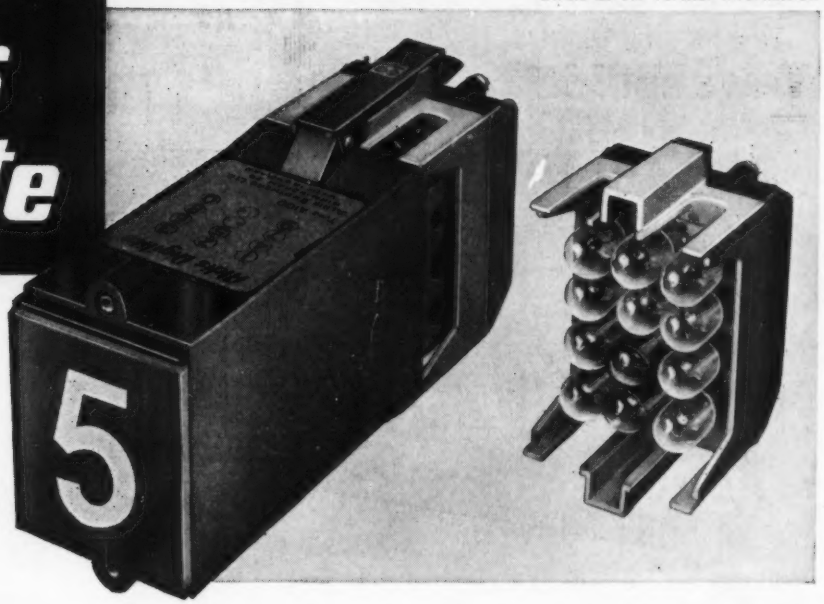
Tel.: CLISSOLD 2365 (4 lines)

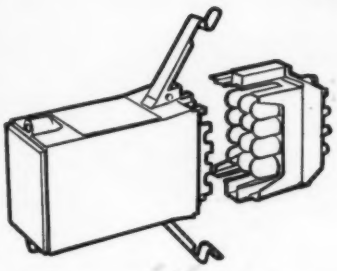
GRAMS: 'OCCLUDE' HACK, LONDON

Circle 27 for further information

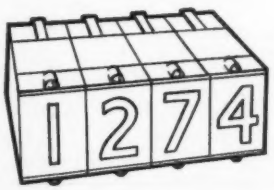
Aldis Digilite

TYPE A100





Quick-release lamp unit for easy replacement of bulbs.



Large numbers (1·2″ high). Any number of units can be grouped together.

A PULLIN GROUP PRODUCT

Improved projection-type In-Line Indicator offers the following unique advantages:

Increased figure size for more effective display.

Quick-release lamp unit for easy lamp change.

Flush panel mounting for wider angle of view and enhanced panel appearance.

The ALDIS DIGILITE comprises 12 lamps in a special quick-release lamp housing and an optical lens system for projecting a brightly illuminated figure-character on to a viewing screen when a lamp is switched on. The main advantage of this method is that the image always appears in the same plane, giving a wide angle of view. Units can be banked together to give (for example) the read-out on a digital voltmeter, and numerous other applications exist.

Angle of View. 75° off axis in all directions.

Lamps. 6·3 volts, 0·3 amps.

Figure Size. 1·2″ high.

Figures. 0 to 9 inclusive, and two decimal points, one before and one after a figure.

Any reasonably alternative set of 12 hieroglyphics could be considered, but if two or more are to be projected at any one time, we should require detailed notice of requirements in good time.

Length. 5·50″.

Height. 3·00″.

Width. 1·562″.

Fixing Holes. 6BA on 2·25″ centres on a vertical centreline of the number.

Panel Aperture. 2·012″ high x 1·562″ wide.

Screen Size. 1·875″ high x 1·562″ wide. The screen has a neutral tint which darkens the background on which the figures are projected, since ambient light must pass twice through the screen material while light from the projected figures passes once only.

Weight. 9 ozs. or 258 grams.

PULLIN

R. B. PULLIN & COMPANY LIMITED

PHOENIX WORKS · GREAT WEST ROAD · BRENTFORD · MIDDLESEX

Cables: PULLINCO, WESPHONE, LONDON

Please note our new Telephone Number: ISLeworth 1212

You should learn more about the Coley

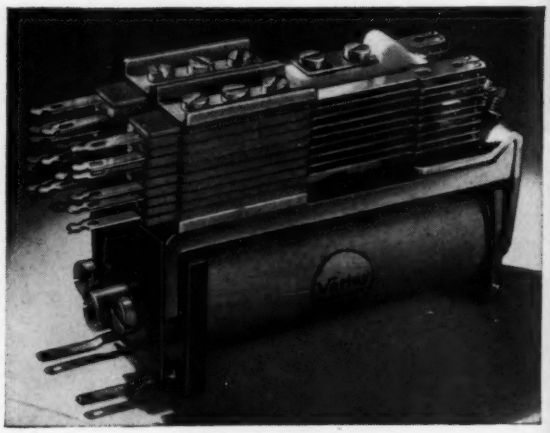
PYROMETER CONTROLLER

Embodying an extremely simple circuit without the use of any electronic components, transistors, lenses or reflectors, the Coley Z5 will control with an accuracy of ·25% at any temperature up to 1600°C.

Leaflet Z5 will tell you all about it.

COLEY THERMOMETERS LIMITED
2-4 LONDON ROAD · BRENTFORD · MIDDX
Phone: Isleworth 4232 *Grams: BRYCO BRENTFORD*

A name that means something!



Varley
REGD. TRADE MARK

P.O.3000 RELAY

. . . a name that means quality All VARLEY relays are built and adjusted to Post Office specification using new piece parts throughout.

COILS All values from .1 to 100 K.ohms can be supplied, also double and sandwich windings.

CONTACTS

TYPE	RATING	MAXIMUM NUMBER
Light Duty Twin Silver.	150V. 0.3 amps	8 M or B 8 C or K
Light/Heavy Duty Silver.	150V. 2.5 amps	8 M or B 4 C.
Light/Heavy Duty Silver.	250V. 2.5 amps	4 M or B 2 C.
Heavy Duty Elkonite.	150V. 5 amps	8 M or B 4 C.
Heavy Duty Elkonite.	250V. 5 amps	4 M or B 4 C.

A name that means promptness. Prototype samples can be supplied within 7 days—full production in 2-3 weeks.

For further details write to Dept. R.3

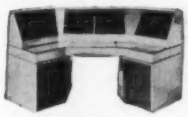
OLIVER PELL CONTROL LIMITED
Cambridge Row, Burrage Road, Woolwich SE18
Telephone: WOOlwich 1422 *Telegrams: Olipel, London, SE18*
TA2547

now buy imlok in any one of 6 convenient stages

WONDERFUL VERSATILE IMLOK SYSTEM! The extended range of connectors and extrusions now available offers you virtually unlimited construction design potential—from a simple case to the most complicated control console that would normally cost a fortune in tool costs! And you can now buy IMLOK in these six convenient stages of manufacture

1. **As individual connectors and with extrusions in 12 ft. lengths**
2. **With connectors pre-drilled ready for assembly with self-tapping screws**
3. **With pre-drilled connectors and with extrusions custom-cut by Imhofs to your lengths and mitred**
4. **As a complete frame-work, ready for fitting with your own panels**
5. **As a complete structure with panels, but unpainted**
6. **As a complete structure, fully finished. You can have either steel or aluminium panels, hammerstone or gloss finish. Bonded plastic finished aluminium panels are available for that extra-special luxury touch. And for extra quick delivery (from 14 days) there is the Savile range of 18 different designs, made to your specified dimensions**

SAVILE TYPE 101



SAVILE TYPE 108

SAVILE TYPE 117

Send now for the new IMLOK Manual — 42 pages, packed with full technical details of every IMLOK component, how to design and how to use IMLOK, and a simplified order form for Savile "tailor-mades"

IMHOFS

ALFRED IMHOF LIMITED Dept H9 Ashley Works · Cowley Mill Road · Uxbridge · Middx · Uxbridge 6231

Export & London Showrooms: 112-116 *New Oxford Street WC1* *Museum* 7878

IMHOFS AGENTS OVERSEAS

AUSTRALIA *Aladdin Industries (Pty) Ltd, Stanmore, NSW*
BELGIUM *Rogelec, Ghent*
CANADA *Measurement Engineering Ltd, Arnprior*
DENMARK *Tage Schouboe, Copenhagen N*
FINLAND *Oy Scienta Ab, Helsinki*
HOLLAND *J. Th. van Reijsen, Delft*
NEW ZEALAND *Imarex Ltd, Auckland C3*
NORWAY *Birger Christensen, Oslo*
SWEDEN *Elektronlund AB, Malmo C*
SWITZERLAND *Walter Blum, Zurich 2/39*
U.S.A. *Bud Radio Inc, Cleveland 3, Ohio*
BRIT. GUIANA *Davsons Caribbean Agencies Ltd, Georgetown*
GERMANY *Sunvic Regler GMBH Solingen*

RAPIDGRAPH

Portable
HIGH SPEED
Pen-recorder

1, 2 or 5 Pen Unit, with Interchangeable pen units of different natural frequencies. Very low power required —e.g. 15 mw. at 15 c/s. This saves the use of amplifiers and their power supplies. Linearity in amplitude within 1%. The Rapidgraph can be used in moving vehicles as the stiffness of suspension makes it insensitive to acceleration and external vibration. With or without paper rewind.

Pen radius 76 mm. Trace 0-44 mm. or ± 20 mm. Exceptional inking system gives reliable, high-quality ink records on paper. Electrical markings on electro-sensitive paper supplied if required. Eight paper speeds up to 100 mm./sec. 120 and 220 Volts A.C.

From

SEFRAM
PARIS

United Kingdom Agents

Dobbie McInnes
(ELECTRONICS) LTD
55 Kelvin Avenue, Hillington, Glasgow, S.W.2. HALFWAY 3364
4 The Mount, Guildford, Surrey. Telephone: Guildford 66385

For a few seconds...

...or several hours

The Hendrey A.C. Adjustable Timer

Incorporates a small self-starting, synchronous motor, which when energised, is arranged to operate a micro-switchette after a predetermined adjustable time delay has expired. Automatically resets on de-energising.

The minimum time delay setting is in all cases 10% of the maximum. Types are available for delays of up to several hours. Adjustment between minimum and maximum settings is by means of indicating knob.

COIL AND MOTOR
—*Wound for 110V. or 230 V. 50 c.p.s. Consumption—8 V.A. approx. total.*

SWITCH
—*Micro-switchette.*

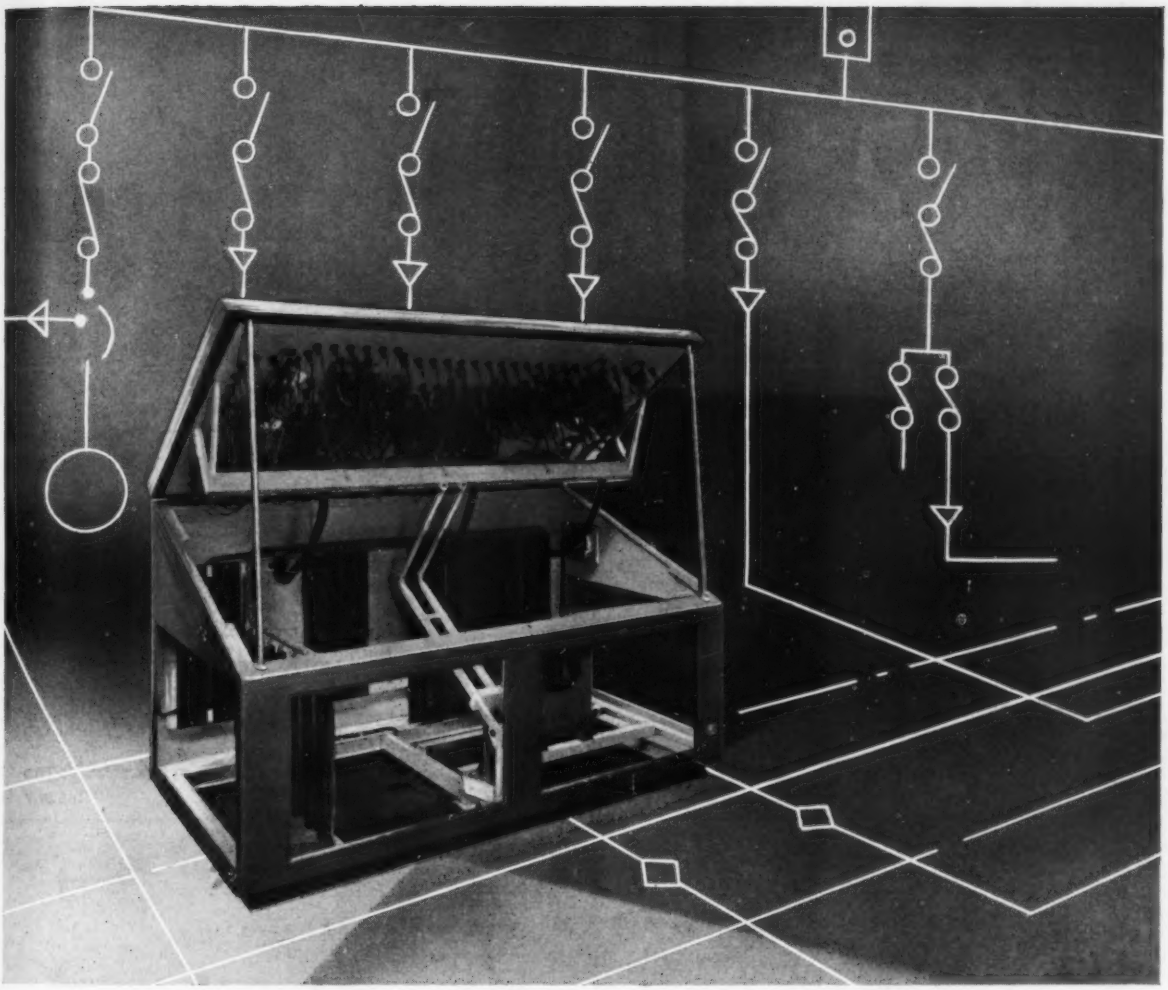
RATING
—*4 amps at 230 V., A.C.*

DELAY
—*The minimum delay setting recommended is approximately 10 seconds.*

DIMENSIONS
—*Width* — 3 *in.* (77 *mm*).
Height — 4½ *in.* (115 *mm*).
Projection — 4½ *in.* (105 *mm*).
4·0·152 *in.*(3·86 *mm*) *dia.fixing holes.*
Weight — 2 *lb.* (0·907 *kg*).

Hendrey Relays

HENDREY RELAYS LTD. BATH ROAD, SLOUGH, BUCKS.
Telephone; Burnham 609/611
MANUFACTURING ELECTRICAL ENGINEERS . CONTROL AND LABORATORY APPARATUS
On Admiralty, Principal Ministries and Post Office Lists, A.I.D. and A.R.B. approved



Let our Engineers help you to turn DESIGNS into DESKS

The Automatic Control Division of C.J.B. includes a staff of experienced Instrument Engineers capable of designing Automatic Control schemes from your flow-sheet.

We can also design and construct Control Panels to any specification required.

Please telephone FULham 7761 for further information.

CJB

CONSTRUCTORS JOHN BROWN LIMITED

AUTOMATIC CONTROL DIVISION

ROXBY PLACE . FULHAM . LONDON S.W.6

Telephone : FULham 7761

Circle 34 for further information

WESTON MOVING COIL RELAYS

Illustrated is the Model S170. Other types include the Model S124, a magnetic contact relay which operates with a minimum power input of 0.004 microwatt and the model S115, a miniature relay, which functions as an "on-off" switching relay.

The simplicity and reliability of relay control for a wide variety of applications has led to the ever increasing use of Weston Moving Coil Relays.
Let us have a note of your relay problems and we will be pleased to advise on the most suitable model for any set of conditions. Enquiries should, if possible, be accompanied by full particulars of both control and local circuits.

SANGAMO WESTON

SANGAMO WESTON LIMITED · ENFIELD · MIDDLESEX

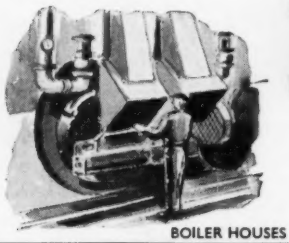
Tel: ENField 3434 (6 lines) & 1242 (6 lines) Grams: Sanwest, Enfield

Scottish Factory: Port Glasgow, Renfrewshire, Port Glasgow 41151 · Branches: London · Glasgow · Manchester · Newcastle-upon-Tyne Leeds · Liverpool · Wolverhampton · Nottingham · Bristol · Southampton

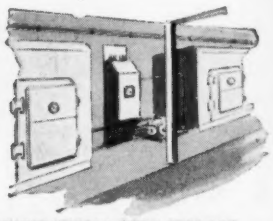
SW/67

Rototherm

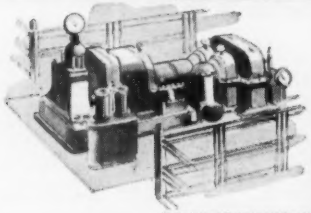
The DIAL THERMOMETER



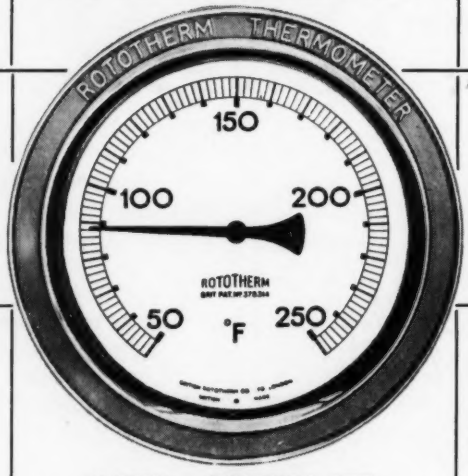
BOILER HOUSES



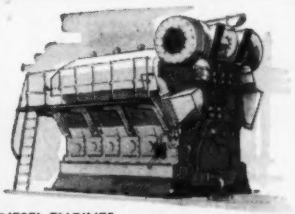
REFRIGERATION & COLD STORAGE



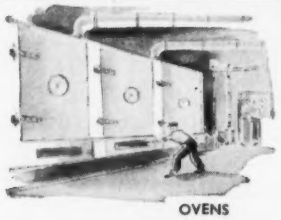
PUMPING STATIONS



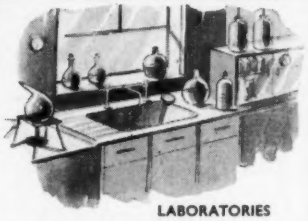
BI-METAL · MERCURY-in-STEEL
VAPOUR PRESSURE



DIESEL ENGINES



OVENS



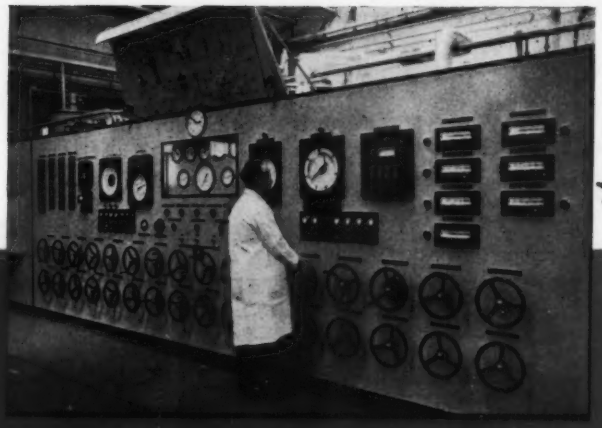
LABORATORIES

THE BRITISH ROTOTHERM CO. LTD., Merton Abbey, London, S.W.19. Tel. LIBerty 7661 (6 lines)

Circle 35 for further information

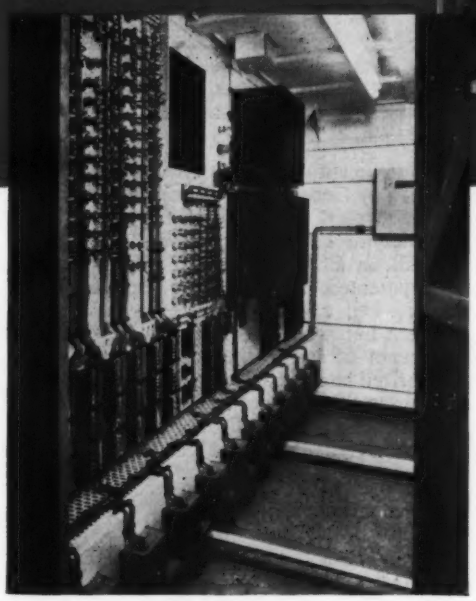
★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Panels Wiring and Complete Instrument Installation



1. Control Panel manufactured for Foster Wheeler Rolls-Royce Facility Test Rig Project.

2. Final inspection before despatch from our factory at Colnbrook.



3. Panels completely piped and wired by fully trained technicians

Our Company are specialist panel manufacturers and Instrument Installation Contractors, we also undertake the design and engineering of instrument projects for Industrial and Nuclear application.

R. HUTCHEON DUTHIE & SON LTD.

18 DAVID ROAD, POYLE TRADING ESTATE, COLNBROOK, BUCKS. *Telephone Colnbrook 2206*

announcement

from

W. BRYAN Savage

we have opened in one of our London factories a

VIBRATION TEST LABORATORY

Manned by experienced Vibration Engineers, the laboratory can accept Vibration work for customers who are unable to carry out their own tests, due either to heavy commitments or equipment not being available.

Range of Vibration Test Equipment

(1) 3,000 lb. thrust vibrator **(Type V1001)** with 10 KW drive amplifier **(Type 10K)** including automatic frequency sweep control. **(Type SFO.1)**

(2) 800 lb. thrust vibrator **(Type V1000B)** with 2 KW drive amplifier.

(3) 550 lb. thrust vibrator **(Type V1000)** with 1 KW drive amplifier.

(4) 250 lb. thrust vibrator **(V999)** with 500 watt drive amplifier.

All enquiries should be sent to Vibration Test Dept.

W. BRYAN SAVAGE LTD

designers and manufacturers of vibrators for industry

17 STRATTON STREET, LONDON, W.1.

Telephone Grosvenor 1926

DaS959/IP

Portable . . .

TYPE MC—1 (MK.III)

CONDUCTIVITY MEASURING BRIDGE

The type MC—1 portable electrolytic conductivity measuring bridge is a truly portable instrument designed to give long and trouble free service in the laboratory or in the field.

The instrument, which is now used by the Electricity Generating Stations and the principal Water Purification Engineers throughout the country, is supplied complete with an ELECTRONIC SWITCHGEAR patented, non-glass, conductivity measuring cell and all accessories, in a convenient hardwood carrying case. The development of low power consumption transistorized circuits, which operate from a small long life dry battery, has resulted in the production of a particularly compact and light-weight precision instrument.

The range of measurement is from $0{\cdot}1$—10^6 micromhos/cm^3.

Price

£66

DESCRIPTIVE LEAFLET MC AVAILABLE ON REQUEST

ELECTRONIC SWITCHGEAR (London) LTD

WORKS ROAD · LETCHWORTH · HERTS

Telephone: Letchworth 1853

London Office: **47 Victoria Street, Westminster, S.W.1**

Telephone: ABBey 2771/5

Circle 39 for further Information

Finding relays a puzzle?

We're old hands at straightening out relay problems.

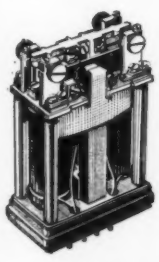
After all, we've been designing and making them for years (over 50 in fact)—big ones, little ones, sensitive ones, general purpose ones; open, dust protected and hermetically sealed, high current, low capacitance, high 'g'—in fact the lot.

We admit that we can't always come up with the answer off the shelf—who can with daily developments in electronics, radar, airborne equipment, nucleonics, reactor instrumentation, etc.? But all of these industries are continually finding Ericsson relays the perfect answer to their problems.

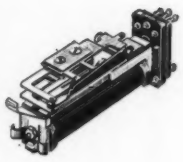
If you are stuck with a very special project and are behind schedule, let us lend you an expert hand.

Help us to help *you*—give us as much information as possible, for an early solution.

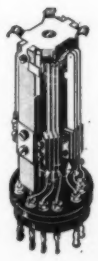
Here are a few of our current miniatures



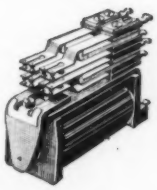
POLARIZED RELAY
Versatile, sensitive and stable. Available with one or two change-over contacts. Dust cover or hermetically sealed. Long or short frame models.



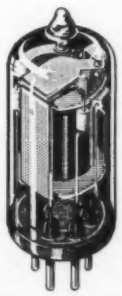
TYPE 1A RELAY
Highly sensitive—non-polarized type with balanced moving system for high 'g' performance. Hermetically sealed. With one change-over.



TYPE 2 RELAY
General purpose type with balanced moving system. Normal and heavy duty contacts up to 4 change-overs. Hermetically sealed.



G.P. RELAY
For general purpose applications. Multi-contacts up to 4 units. Open, dust cover or hermetically sealed with normal, heavy duty or low capacitance contacts.



MGL RELAY
Specially designed for electronic and nucleonic applications. One change-over contact. Fits B7G base. Also available with metal can.

Full details of these and other relays can be obtained from:

ELECTRO-MECHANICAL DIVISION
BEESTON · NOTTINGHAM · ENGLAND

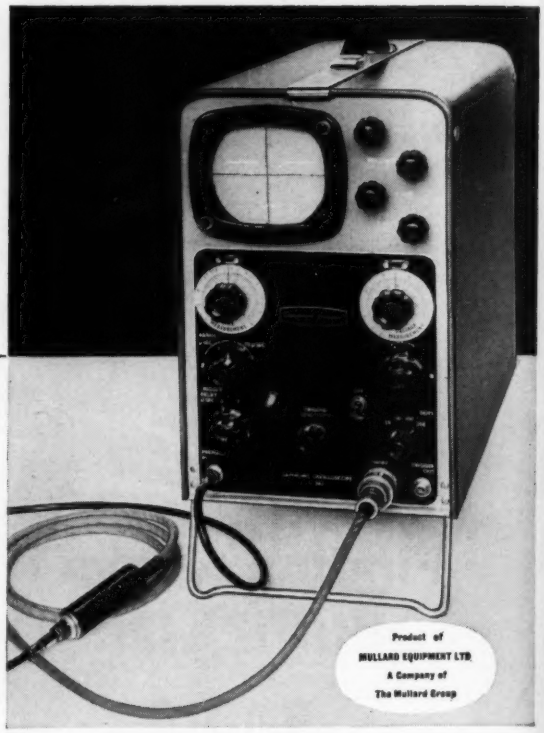
ERICSSON

Ericsson Telephones Limited
Head Office: 22 Lincoln's Inn Fields
London, W.C.2. Tel. HOLborn 6936

E197-86

Circle 40 for further information

The oscilloscope with 2 Milli-micro seconds rise time



Extremely compact & portable · Sensitivity 150 mV/cm
Can handle repetitive pulses of random separation
Bright display · Inexpensive

Working on a novel sampling principle, the L362 provides nucleonic and electronic engineers with an inexpensive oscilloscope capable of recording pulses of extremely short duration.
The L362 oscilloscope has been developed from a design originated by the United Kingdom Atomic Energy Authority Research Establishment, Harwell.

DIMENSIONS: *only 14½ in x 8¾ in x 18 in and weight 27 lb. (12·2 kg)*

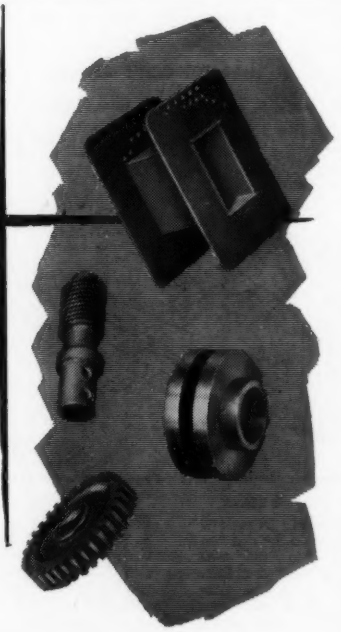
Write for full technical details:—

RESEARCH AND CONTROL INSTRUMENTS LIMITED
Instrument House, 207 King's Cross Road, London, W.C.1

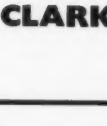
(RCL0423)

PIRTOID

SYNTHETIC RESIN BONDED LAMINATE



brings you
MATERIAL SOLUTIONS
to your
CURRENT PROBLEMS



. . . because the range of PIRTOID Paper and Fabric base laminates affords all the machining qualities needed with consistent uniform dielectric and mechanical strength. Read this booklet, sent gladly on request.

H. CLARKE & CO. (MANCHESTER) LTD
Atlas Works · Patricroft · Manchester
Telephone Nos. ECCLES 5301-2-3-4-5

dm CK4

Circle 41 for further information

Circle 42 for further information

Quartz Crystal Controlled
TRANSISTOR OSCILLATOR 100Kc/s

FREQUENCY: 100 Kc/s.

FREQUENCY TOLERANCE: ± ·015% over temperature range — 10°C. 60°C.

FREQUENCY STABILITY: Less than 5 parts in 2 million change with a 10% change in supply voltage.

OUTPUT: 3 Volts on open circuit conditions. 1½ Volts across a 20,000 ohm load.

POWER SUPPLY: 6 Volts D.C. Power consumption 5 milliwatts.

WEIGHT: 30 grams.

ALSO AVAILABLE IN FREQUENCIES 1 and 5 Mc/s.

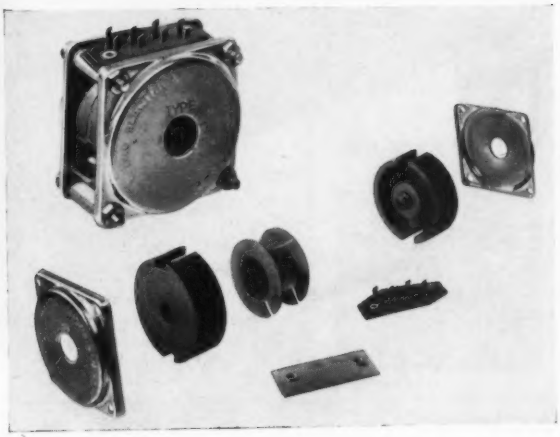
The design of quartz crystal controlled oscillators is of a specialist nature, and there are many problems associated with their use. In order to obtain the best performance and consistent operation, it is often desirable that not only the circuit configuration but also the physical layout should be related to the design of the crystal unit used.

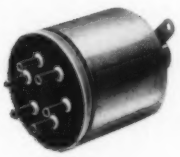
As established manufacturers of such units, we have developed a packaged crystal controlled transistor oscillator. Available in two forms, they will provide an accurate 100 Kc/s. suitable, for example, as a time base master frequency.

By the provision of a suitable power supply, these units may be used as portable frequency sub-standards.

Gecolite

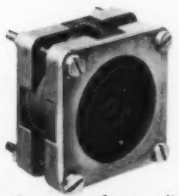
Adjustable FERRITE CORES





A series of adjustable ferrite core assemblies for use as high quality inductors at frequencies up to approximately 300 Kc/s is readily available.

Based on our range of Gecolite cores these assemblies are directly interchangeable with many non-adjustable assemblies already in use.



In many cases therefore it is possible to dispense with the slower and more tedious methods of adjustment that have to be employed. Write for Data Sheet 592.

A range of non-adjustable cores is also available. Data Sheet 591.

SALFORD ELECTRICAL INSTRUMENTS LIMITED

TIMES MILL · HEYWOOD · LANCASHIRE *Telephone:* Heywood 6868

London Sales Office: *Telephone:* Temple Bar 4668

A SUBSIDIARY OF THE GENERAL ELECTRIC CO. LTD. OF ENGLAND

Circle 43 for further information

Automation
CONTROL EQUIPMENT
depends on Mumetal and HCR Alloy

TYPE 225

MUMETAL and HCR ALLOY are features of jet engine fuel control circuits, magnetic amplifiers, transistor power supplies, and other electronic control devices.
Auto-Pilot equipment Synchros, and Servo mechanisms incorporate SUPER MUMETAL, MUMETAL, and RADIOMETAL ALLOYS.
PERMENDUR and RADIOMETAL are used in ultrasonic generators for etching and cutting glass, chemical mixers and agitators, metal flaw detectors, and vibration equipment. VACUUM MELTED ALLOYS, gas-free for glass sealing, and controlled expansion/temperature alloys are standard productions together with stock for further alloying.

Push/pull Magnetic Amplifier Type 592 embodying our laminations Type 225. By courtesy of Electro Methods Ltd. (Above)

Mumetal Laminations
are incorporated in the MAGNETIC AMPLIFIERS used for REACTOR INSTRUMENTATION at DOUNREAY ATOMIC POWER STATION

TELCON METALS

THE TELEGRAPH CONSTRUCTION & MAINTENANCE CO LTD
Metals Division · Telcon Works · Manor Royal
Crawley · Sussex · Telephone: Crawley 1580

THE BRYANS
"X" & "Y" Co-ordinate Plotting Table Catalogue No. 1806

- A well-designed and robust instrument.
- A high degree of plotting accuracy is maintained with a good speed of response.
- Plotting area 15" x 10" on paper.

for further details write to:—
BRYANS AEROQUIPMENT LIMITED

Specialists in precision measurement of pressure, temperature and speed. Design and production facilities available for test equipment and multiple panel building including electrical and electronic work.

WILLOW LANE,
MITCHAM JUNCTION,
SURREY.
Tel. MITCHAM 5134 (5 Lines)

Circle 44 for further information

Circle 45 for further information

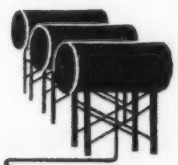
keeping an eye on the head...

from hundreds

of feet away

Designed for measuring non-conducting fluids in high pressure or vacuum tanks, the FCI PACITOR ELECTRONIC TANK CONTENTS GAUGE has proved most efficient. It takes up little room and needs minimum maintenance. In installations where the total liquid capacity runs into thousands of gallons stored in a number of tanks, Pacitor will give an accurate indication of the summated or individual tank contents. The Gauge has been certified safe for gases in Groups II and III.

The FCI HYDROSTATIC TANK CONTENTS GAUGE measures the head of liquid in almost any type of non-pressurised tank, wherever it's situated and regardless of size and height. The gauge is of the remote-reading type and there is a wide choice of different kinds of installation to suit individual needs. It is suitable for measuring corrosive and non-corrosive liquids; liquids containing solid matter in suspension such as paper pulp; viscous fluids such as syrups.



Full technical details from:

FIRTH CLEVELAND INSTRUMENTS LIMITED

Byron House, 7-8-9 St. James's St., London SW1 A Member of the Firth Cleveland Group FC

CRT186

Circle 46 for further information

WHY Taylor Panel Meters?

BECAUSE OF THESE OUTSTANDING FEATURES—

- ★ **Centre Pole Movements with high torque to weight ratio.**
- ★ **Very high sensitivity (commencing from 5 micro-amps).**
- ★ **Inherent magnetic shielding.**
- ★ **Extreme robustness and rigidity.**
- ★ **Stick free operation.**
- ★ **Permanent method of dry balancing.**
- ★ **Exceptional coil clearance—trouble-free gap.**
- ★ **Proven reliability.**
- ★ **Competitive prices : Prompt delivery for prototypes.**

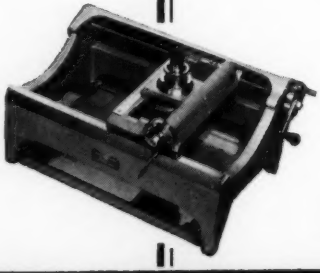
Taylor Centre Pole Meters can be supplied with scale lengths from 2 in. — 5 in. in round and rectangular cases.

Taylor

Write for full details and free catalogue to

TAYLOR ELECTRICAL INSTRUMENTS LTD. (Dept. I.P.)
MONTROSE AVENUE, SLOUGH, BUCKS. *Telephone: SLOugh 21381*

Two Dimensional Measuring Microscope



CAT. No. 6147

Pye Instruments

The Two-Dimensional Measuring Microscope enables precision measurements to be taken in two directions, lengthwise and across, without further alignment of the object under inspection. Opaque and transparent items — in fact, all kinds of materials and shapes which do not lend themselves to other methods of micrometry—can be measured quickly and accurately. Excellent for measuring photographic data; oscilloscope readings; the marking of precision work; inspection of intricate parts encased in glass etc. Available in metric or English units.

Please write for further details on our range of measuring microscopes and precision cathetometers.

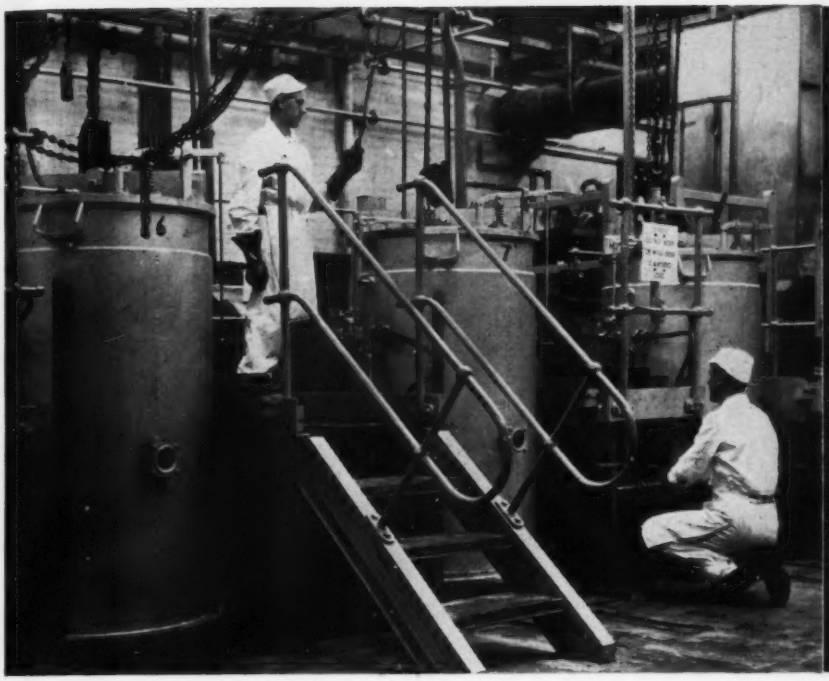
- ★ *Extreme accuracy. Resultant accuracy is better than ± 0.01 mm or ± 0.00039 in when traversed over the full range of 20 cm (lengthwise) and 10 cm (across). Accuracy improves with use.*
- ★ *Fitted with micrometer heads reading direct to 0.01 mm.*
- ★ *Lead screws are aged, precision ground and corrected to tolerance of ± 0.01 mm. Large diameter. 2 mm pitch.*
- ★ *Backlash effectively eliminated by means of fully floating split whole nuts.*
- ★ *Spring vee guides ensure accurate alignment of the carriage on the crowns of the lead screw thread.*
- ★ *Fine optical definition and critical focusing depth. Fitted with reticule. Magnification x5, and x20. (Other magnifications available).*

SCIENTIFIC PYE INSTRUMENTS

W. G. PYE & CO. LTD.
GRANTA WORKS NEWMARKET ROAD CAMBRIDGE ENGLAND
Telephone: Cambridge 54411 (5 Lines) *Telegrams: Pye Cambridge*

Circle 47 for further information

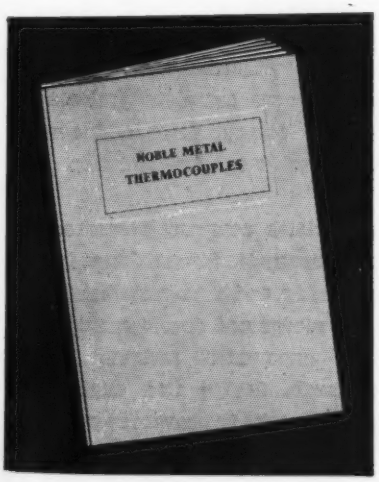
Circle 48 for further information



High-Frequency vacuum casting furnaces for the production of uranium reactor fuel elements. Temperature control is effected by means of platinum:rhodium-platinum thermocouples

High Temperature Control

In *all* industries employing high temperatures, precise control inevitably depends upon accurate measurement. Hence the widespread use of the JMC noble metal thermocouple—the most reliable practical method.



"NOBLE METAL THERMOCOUPLES" by H. E. Bennett, F.I.M. now being reprinted, surveys the use of the noble metal couple in research and industry and discusses different applications. Copies are sent free on request.

Information regarding the properties of the platinum metals and their industrial application is freely available.

Johnson Matthey

NOBLE METAL THERMOCOUPLES

JOHNSON, MATTHEY & CO., LIMITED, 73-83, HATTON GARDEN LONDON, E.C.1

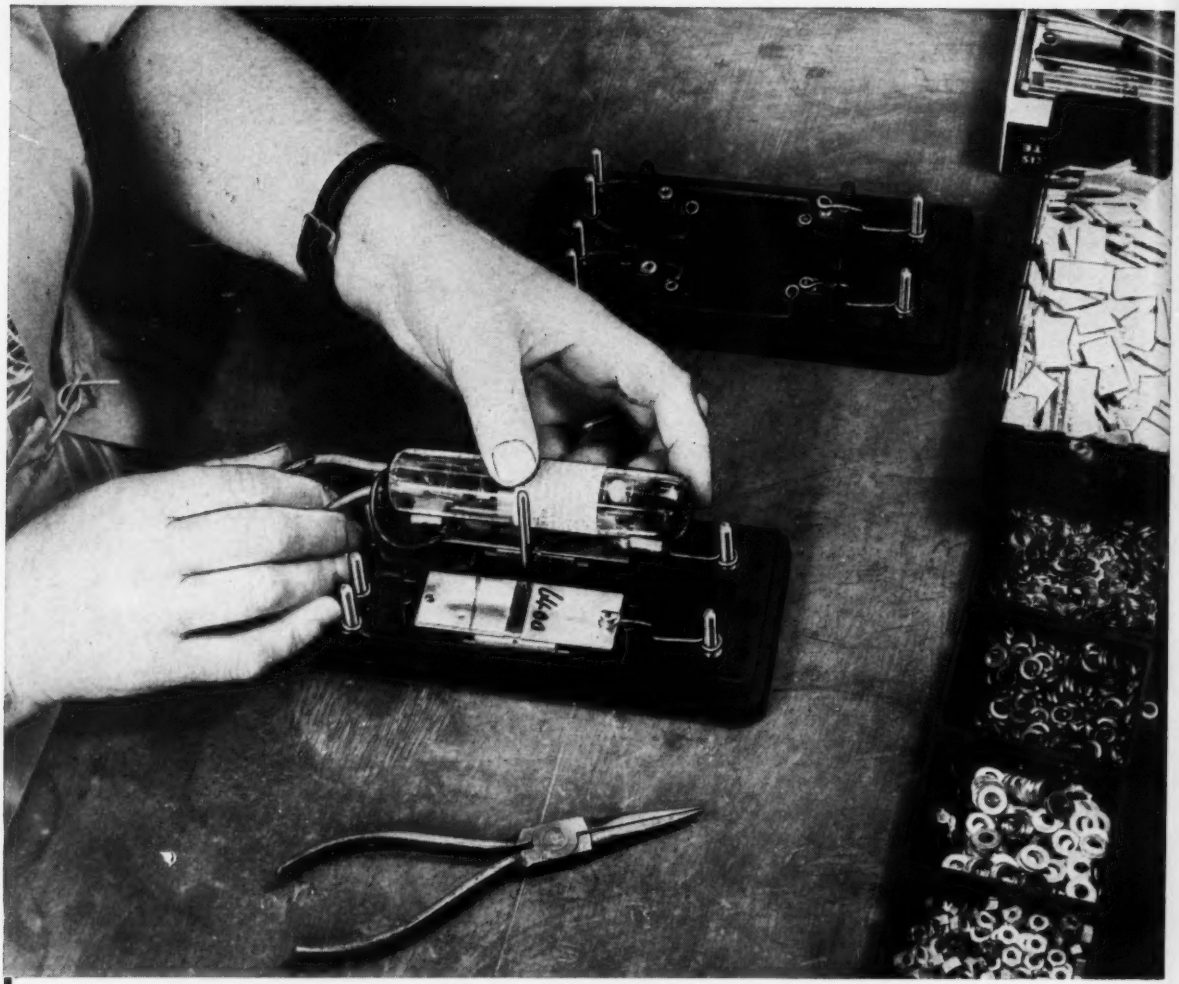
Telephone: Holborn 6989

Vittoria Street, Birmingham, 1. Telephone: Central 8004.

75-79, Eyre Street, Sheffield, 1. Telephone: 29212

181

Circle 49 for further information



Assembly of hot wire vacuum switch relays.

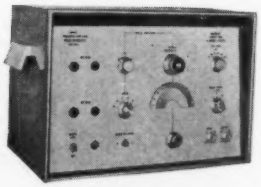
SUNVIC

instruments and complete instrumentation

Sunvic manufacture a variety of pneumatic, electronic and electro-thermal instruments; in addition they engineer complete projects for integrated process measurement and control systems including data transmission and logging.

Sunvic, an all-British company pioneered the introduction of pneumatic force-balance instruments in this country, and has a vast background of technical knowledge and development in the application of pneumatic instrumentation. Extensive research, design and engineering resources can be brought to bear on any project.

Components and electronic instruments



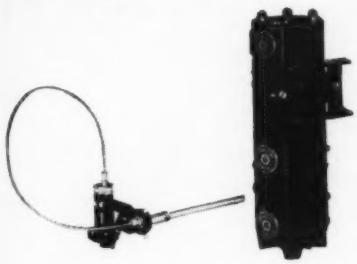
Precision Pulse Generator: for use in any application requiring a shaped pulse of stable and accurately known amplitude. Pulse widths of 1, 5, or 25 μsecs. Main Amplitude control over 0-40V to a linear accuracy of ±80mV and incremental control over 0–1.24V to ± 2mV. Overall amplitude stability better than ± 0.025%.

High Speed Potentiometric Recorders: single or multi-trace, a choice of 13 different input units and numerous additional facilities; 27 different chart speeds from 1" per hour to 3" per minute. Can be supplied with speed of response of 1 sec. and guaranteed calibration accuracy of ± 0.5% f.s.d.

Pneumatics

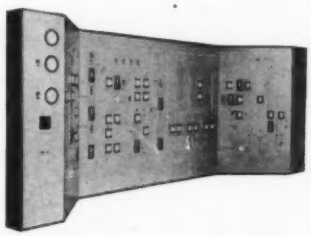
Controllers: will accept any pneumatic signal from transmitters giving output up to 50 p.s.i. Will withstand 120g shock with less than 1% zero shift: ambient temperature limits −60° F. to +225° F. Sensitive to changes in measured variable of 0.01%.

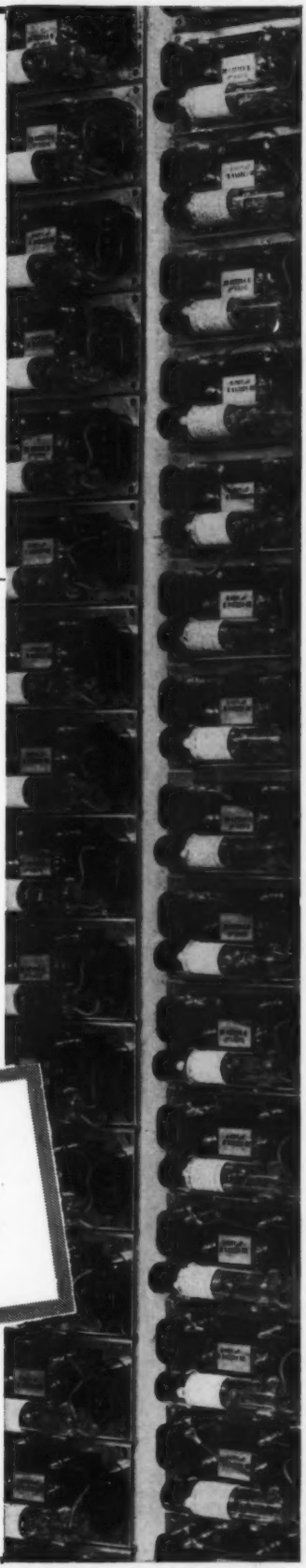
Temperature Transmitters: true constant volume type, helium filled. Sensity 0.01% of full scale. Temperature spans 50° F. to 900° F; ambient limits −60° F. to +200° F. Max. temp. 1,000° F; min. temp. −328° F.



Complete systems

Sunvic will design and engineer complete projects for integrated systems of process measurement, recording and control, including data transmission and logging. This graphic control panel is one supplied for the platforming unit at the Anglo-Iranian refinery, Aden.





Send for details

of Sunvic pneumatics, components or nuclear instrumentation to:

SUNVIC CONTROLS LTD

P.O. BOX 1, HARLOW, ESSEX.
TEL: HARLOW 25271

SUNVIC

An A.E.I Company

Instruments and complete instrumentation

Circle 50 for further information

EVIDENCE IN CAMERA

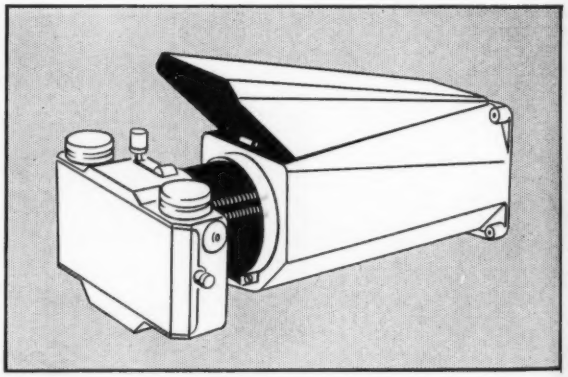
OSCILLOSCOPE CAMERAS BY JLT GROUP

The range of JLT Cameras have been specially designed for use in conjunction with most general purpose oscilloscopes — either by single shot recordings with the C.100 camera (illustrated above) or a continuous film record using the C.200. The third camera in the JLT range is the C.400 which enables the records to be viewed within 60 seconds of exposure — without the use of a darkroom.

C.100
- * Adjustable magnification ratio
- * Interchangeable lenses f1-f3.5
- * 35 mm. film or paper

C.200
- * Adjustable magnification ratio
- * Interchangeable lenses f1-f3.5
- * 35 mm. film or paper
- * Speed range ½" per sec. to 75" per sec.

C.400
- * Finished prints within one minute from this single shot camera
- * Easily read prints 3" x 4"



There is a wide range of hoods available to suit most popular Oscilloscopes. All cameras are interchangeable in any hood. The wave form may be viewed through a 'safe-light' glass whilst recording takes place.

JLT GROUP

J. LANGHAM THOMPSON LTD.

BUSHEY HEATH · HERTS · ENGLAND

Telephone: BUShey Heath 2411 Grams & Cables: "Tommy Watford"

INSTRUMENT Practice
AUTOMATION & ELECTRONICS

Editor: J. T. Miller, B.Sc., F.Inst.P.

Assistant Editor: H. M. T. Oesterley, B.Sc.

VOL. 13. No. 9

CONTENTS September 1959

	Page
Displacement Calibration During the Recording of a Sinusoidal Movement *By G. Hodgson, A.Inst.E. and J. McKenzie, A.M.I.Mech.E.*	917
Trends and Developments in Instrumentation in the U.S.A. *By A. J. Maddock, D.Sc., F.Inst.P., M.I.E.E.*	933
Theoretical Models of Pneumatic Control Apparatus *By R. Jackson, M.A.*	926
Resilient Buffing Wheels for Precision Potentiometers and Instruments. Part II *By K. F. Shrubb, B.Sc.(Eng.), A.M.I.E.E., A.M.I.Mech.E.*	932
Automatic Machine Tool Control Systems	938
Computers and the Electronic Office. Part 5. Some Economic Aspects of the Commercial Use of Computing Systems *By R. H. Williams, A.I.B., F.Inst.D.*	942
BTH Systems Laboratory	945

Regular Features

Commentary	915	Export News	966
Book Review	921	Forthcoming Events	968
New Instruments	947	Publications Received	968
News of the Industry	961	Personalities	970

Published by **UNITED TRADE PRESS LIMITED**
9 GOUGH SQUARE, FLEET STREET, LONDON, E.C.4
Telephones: FLEet Street 3172-3-4-5 Telegrams: MARKEBA LONDON

Technical articles will be gladly considered for publication, payment being made by arrangement. Articles should preferably be from 3,000 to 4,000 words, but no rigid limit is imposed. Manuscripts should be typewritten, in double spacing, on one side of the paper only. Diagrams should be on Bristol board, tracing cloth or tracing paper, drawn and lettered in Indian ink, symbols to the relevant B.S. specifications. For half-tone illustrations, glossy prints are preferable. While every care is taken of MSS. submitted, no responsibility can be accepted in case of loss.

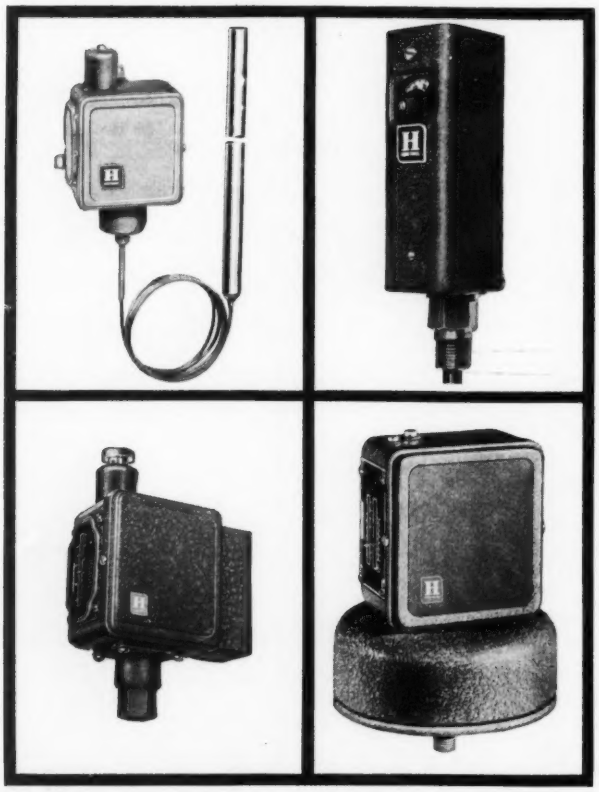
Annual Subscription United Kingdom £2-10-0, postage free. (Single copies 4/6.) $8.50 United States and Canada. £3 Sterling all other countries.

Circle 51 for further information

Spend less to save more

with Honeywell Non-Indicating Controllers

Inexpensive, 'off-the-shelf' Honeywell control systems are already proving their worth in electroplating, solvent degreasing, brick drying, batch pasteurising, textile sizing, and a host of other important applications. The wide range of standard controllers readily available means that increased economy, efficiency, safety, can now be brought to every plant and process . . . to *your* plant and process.



FOR TEMPERATURE

(Left) Remote Bulb Temperature Controllers—on-off or modulating.
For temperature between 0° and 700°F.
Operates switch contact or motorised valve.

(Right) Fast-acting Aquastat—two-position Microswitch control of liquids.
Speedy action obtained by thin-walled vapour tension type bulb.

FOR PRESSURE

(Left) Pressuretrols—two-position and proportioning models for liquid and gas pressure from 0-300 psi.
For pressure or liquid level.

(Right) Vaporstats—low range pressure control unit. Suitable for high-limit control, liquid level, etc.

And Honeywell Motorised Valves will operate with all types of Non-Indicating Controller to give two-position, floating and proportional control.

For further information write or send the coupon TODAY
Honeywell Controls Limited, Ruislip Road East, Greenford, Middlesex. WAXlow 2333

I am interested in the application of Non-Indicating Controllers
Please send: *(Tick where appropriate)*
Full information ☐
Address of your nearest branch office ☐

NAME .....
COMPANY .....
POSITION .....
ADDRESS .....
.....
I.P.

Honeywell
First in Control

INSTRUMENT Practice
AUTOMATION & ELECTRONICS

COMMENTARY

The Society of Instrument Technology The reception of the programme for 1959-60 of the Society of Instrument Technology, with its ever-increasing number of activities, is a reminder of the progress made by the Society since the memorable first meeting in May, 1945. Casting one's mind back to those days, with the war scarcely over, the circumstances were anything but encouraging for the start of a new society associated with a specialised field of technology. It says much for the faith and enthusiasm of the small band of people who undertook this task, for there was much to be done and little in the way of facilities to assist them in bringing the Society into being. One saw something of the labour involved, particularly that of the honorary secretary who willingly undertook practically a full-time job in addition to his own very responsible post in the industry. It is a pleasure to see that Mr. L. B. Lambert is still honorary secretary after fourteen years, and no doubt he reflects, as many of us do, on the progress made during that period. For what have we now?

In London, the one section has grown into three. There are now a Control Section, a Data Processing Section and a main meeting for discussing general instrumentation. A total of eighteen meetings are to be held in the coming session, roughly three per month, and a glance at the papers' titles indicates the very wide range of interest. But, in addition to the London activities, there are now no less than fourteen sections in the provinces: Bristol, Cheltenham, Chester, East Midland, Fawley, Grangemouth, Liverpool, Manchester, Midland, Newcastle, Scotland, South Wales, South Yorkshire and Tees-side. Some members of these sections have large distances to travel to the meetings, and many make these journeys under difficult conditions in winter time.

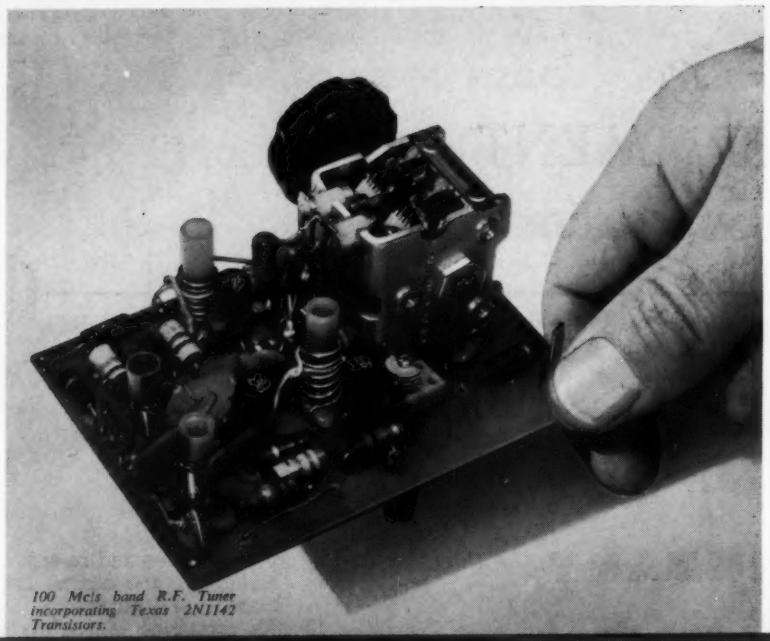
The membership is now some thousands, and is growing all the time. This must be due to a realisation of the objects of the Society which briefly are:

(1) The advancement of instrument technology by the discussion and co-ordination of information relating to the design, application and maintenance of instruments.
(2) The provision of opportunities for discussion, particularly between the designers and manufacturers on the one side, and users on the other.
(3) The provision of opportunities for discussion and collaboration between the Society and other societies.
(4) The encouragement of technical education for persons who want to enter or who are already in the industry, dealing with instrument research, design, manufacture, or use.
(5) The encouragement of research into problems relating to instrument technology.
(6) To participate in discussions promoting the standardisation of instruments and accessories.
(7) To participate in discussions leading to a commonly acceptable terminology.
(8) To enhance the status and prestige of those employed in the industry.

If the Society continues to apply these objects in the future with the same vigour as in the past one wonders what the meetings will be discussing fourteen years hence. The instrumentation of the latest manned moon rocket or a new miniature computer for the complete control of industrial processes? These seem a little fantastic at the moment, but with the rate of development in certain fields one cannot be certain what the future holds. One thing is certain, the Society will be there playing its role in accordance with the aims expressed above.

Exhibitions A new exhibition season will soon be upon us. This is not going to be a list of forthcoming exhibitions, but one has seen advance information regarding the 1960 Instruments, Electronics and Automation Exhibition. This promises to be, by a large margin, the largest and best of these exhibitions to be held. In view of the Continental trade developments since the last exhibition in 1958, this may prove to be the most significant show for the industry, and we shall look forward to seeing the final figures for the number of exhibitors.

Circle 52 for further information



100 Mc/s band R.F. Tuner incorporating Texas 2N1142 Transistors.

NOW!
600 Mc/s TRANSISTORS
FROM TEXAS

Complete transistorisation of highband v.h.f. and of much u.h.f. equipment is now a reality with the introduction of two new Texas Instruments diffused-base germanium transistors, the 2N1142 and the 2N1143.

With an alpha frequency cutoff of 600 Mc/s for the 2N1142 and 480 Mc/s for the 2N1143, and a total dissipation up to 750 mW at 25°C these transistors will have wide application in airborne communication and navigation equipment. For added reliability these diffused-base transistors are enclosed in the JEDEC-T05 welded case.

For maximum mechanical strength and heat dissipation, the Texas diffused-base construction mounts the wafer directly on to the header.

TEXAS INSTRUMENTS LIMITED

TELEPHONE: BEDFORD 68051 DALLAS ROAD BEDFORD CABLES: TEXINLIM BEDFORD

T.37

(*a*) *Without dynamic calibration* (*b*) *With dynamic calibration*

Fig. 1. *Film record of extrusion*

By G. HODGSON, A.Inst.E. and J. McKENZIE, A.M.I.Mech.E.
D.S.I.R., National Engineering Laboratory, East Kilbride, Glasgow

Displacement Calibration

During the Recording of a Sinusoidal Movement

An account is given of a stroke calibration unit, consisting of a photo-transistor pick-up and a pulse generator, which was developed and constructed at the laboratory for applying pulses, of equal displacement intervals, to a sinusoidal stroke trace of an extrusion test record.

The separate units are described and a full explanation of their operation is given. Other possible applications of the unit are discussed, the pulse generator having been designed with this in view.

Introduction

DURING a typical extrusion carried out in a 150 ton crank press, the load stroke-temperature-time trace of the operation was continuously recorded by filming a multi-channel c.r.o. display[1]. Fig. 1 (a) is a typical test record showing the variation of punch stroke and extrusion load with time. The punch stroke, which was recorded by means of a variable co-axial condenser, is shown as a sinusoidal motion characteristic of the crank press. The extrusion load is recorded by means of a parallel plate condenser type load cell[2].

A careful study of the effect of varying certain factors on the load-punch stroke characteristic was included in the extrusion research programme. Although the film test record was continuous, an accurate analysis of the record was difficult due to the high speed of the punch and the rapid rise of the extrusion load at the initiation of extrusion, and the tendency of the load to rise slightly prior to punch-metal contact due to trapped lubricant pockets, etc. It had been found that a slight error in the analysis of the initial part of the extrusion film record, which had a linear time abscissa, resulted in a much larger error when the characteristic was plotted against a linear displacement abscissa.

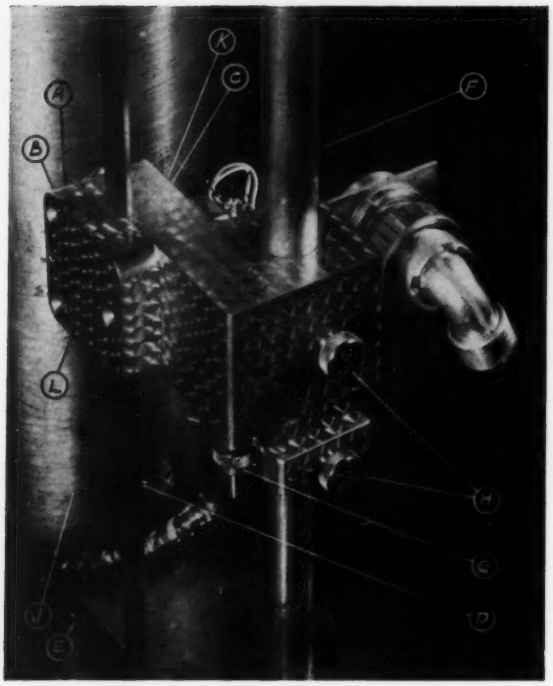
Increasing the film speed of the former record enabled the beginning of the test to be shown more accurately but resulted in a lengthy test record which was inconvenient for subsequent analysis and did not indicate the instant of punch-metal contact. There was a definite need for a pulse superimposed on the film record at equal intervals of punch displacement which would allow the film record to be extended and indicate clearly the instant of punch-metal contact; this would dispense with a preliminary stroke calibration, compensate for any slight change in sensitivity over the period of the test series, and result in a more accurate and quicker method of analysis.

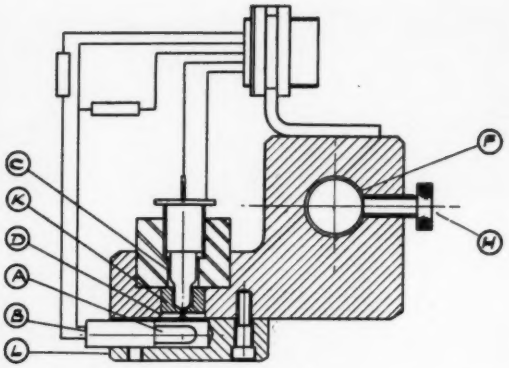
Object

To develop and construct a unit for continuous displacement calibration of a sinusoidal stroke trace.

Description and Functioning of Units

A negative voltage of more than 30 volts applied to the modulator terminals of the c.r.o. would successfully blank out the beam. In view of the accuracy required and the operating speed, a mechanical triggering system was unsuitable. Hence, a photo-transistor pick-up unit and a pulse generator giving the required output were developed and constructed.





▲*Fig. 2(b). Sectional plan of photo-transistor pick-up*

◀ *Fig. 2(a). Photo-transistor pick-up in situ*

Photo-transistor Pick-up Unit

Fig. 2 (a) and (b) shows a photograph and a sectional plan of the pick-up unit. A Mullard OCP 71 photo-transistor (A) mounted on a Tufnol collar (B) was positioned immediately adjacent to lamp (C) with a $\frac{1}{16}$ in. thick ground steel strip (D) sliding between them. A 1·2 in. length of steel strip (D) had holes of 0·020 in. bore drilled at intervals of 0·1 in., the accuracy of their spacing being within 0·0001 in. It was not necessary to use a material of lower coefficient of linear expansion than mild steel for the strip (D) since, as can be seen in Fig. 2 (a), it was strapped, by means of brackets (E), to the travelling part of the co-axial stroke gauge (J) which was also made of mild steel.

The pick-up was mounted on the stationary guide rail (F) and its position accurately adjusted by means of a thumb screw (G) and held by locking screws (H).

The light from the lamp was directed through an aperture (K) of 0·020 in. bore and on to the photo-transistor through a hole of $\frac{1}{16}$ in. bore in the transistor holder (L). It impinged on the transistor only when one of the holes in the sliding strip (D) passed the light aperture. The sliding clearance between parts (K), (D) and (L) was 0·001 in. Hence, when the down stroking ram platen of the crank press was put into operation, the top half of the stroke gauge and sliding strip were set in motion. At each 0·1 in. interval of stroke, over 1·2 in. from punch bottom dead centre, a series of pulses was obtained from the energised transistor which triggered the pulse generator. The output from the pulse generator modulated the beams on the c.r.o. equipment as described below.

Fig. 1 (a) and (b) shows a test record of an extrusion without and with the stroke calibration pulses. The variation of the 0·1 in. stroke pulses with the 0·02 sec time marker pulses can be seen.

Pulse Generator

The pulse generator was designed such that, when triggered by some external signal, it produced a negative pulse greater than 30 volts and of any pre-determined length between 10 μsec and 1 msec. In order that it should be as versatile as possible, the instrument also provided a positive output pulse, and a fast positive pulse corresponding to the leading edge of the output pulse is available. These may be triggered from the leading or trailing edge of the input signal, which can be either positive or negative and of any waveform. A general view of the instrument is shown in Fig. 3.

The circuit diagram shown in Fig. 4 can be roughly divided into four sections, namely:

(a) Input amplifier and selection of input polarity V1 and V2
(b) Schmitt trigger circuits V3 and V4
(c) Kipp relay pulse-generating circuits V5 and V6
(d) Output pulse amplifier V7.

(a) *Input Amplifier*

Two outputs are obtained from a conventional pentode amplifier V1 using a CV138 valve, one from the anode and one from the cathode. This valve, biased to work on the comparatively straight part of the I_a/V_g characteristic, could accommodate positive or negative inputs. In order to feed a negative signal to V2 irrespective of input polarity, the anode output (180° phase shift) or cathode output (in phase) may be selected. The conventional pentode amplifier, V2, was *RC* coupled to V1, its screen being taken to a potential divider R6 and R8. The screen load R6 is made variable to allow the anode voltage of V2 to be set at the correct value in order to have d.c. coupling to the control grid of V3.

(b) *Schmitt Trigger Circuit*

Valves V3 and V4 are used in a Schmitt trigger circuit which is essentially a cathode-coupled bistable multivibrator[5, 6]. In this type of circuit two stable configurations may exist: the first when V4 is conducting, then the cathode of V3 will be raised positively

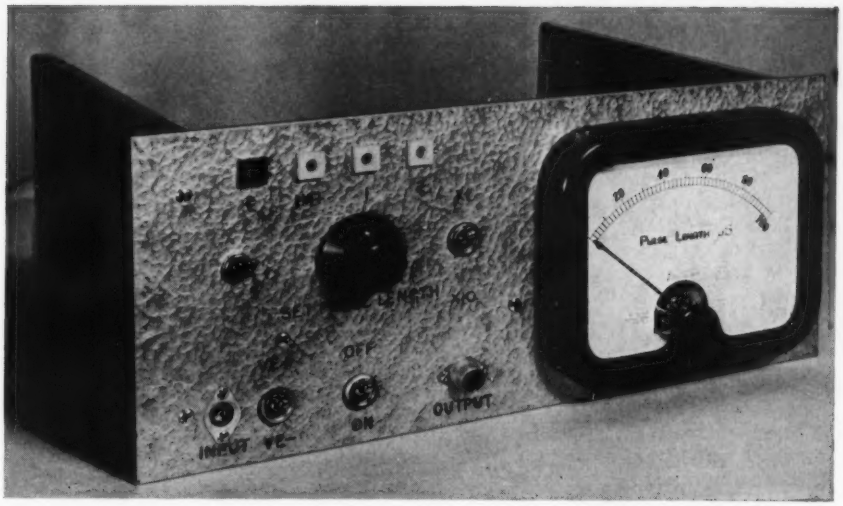
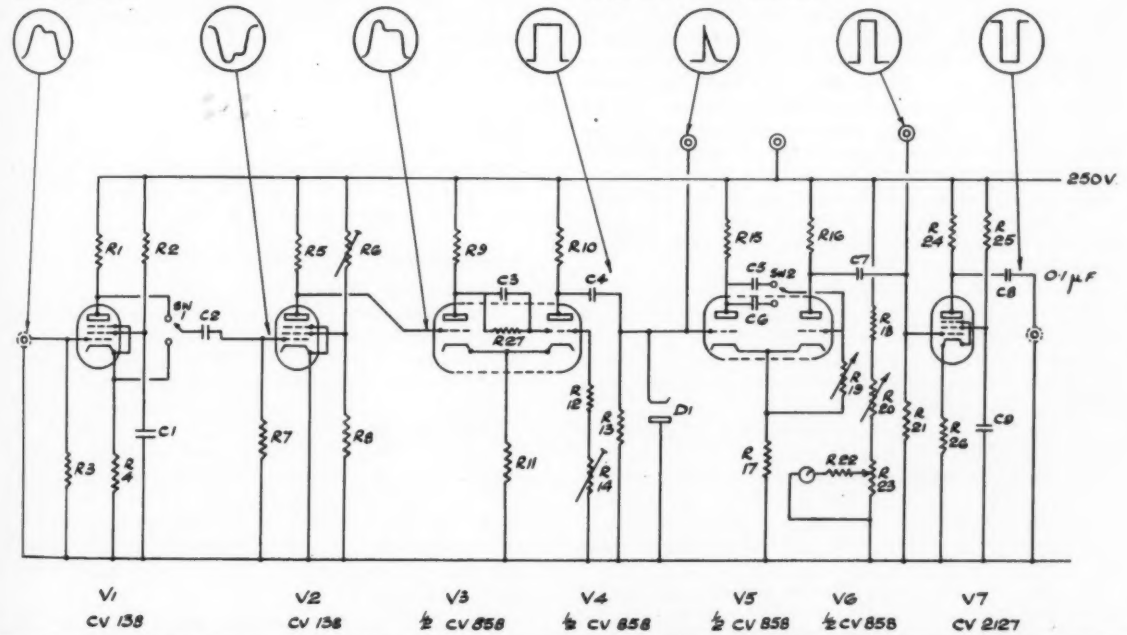


Fig. 3.
Front view of pulse generator

due to current through R11, and V3 will be cut off; the second stable state occurs with V3 conducting, reducing the anode voltage of V3 and thus the grid voltage of V4, resulting in V4 being cut off. In the circuit under discussion V3 can be considered as being cut off*, and V4 conducting. If a positive signal is applied to the grid of V3, then the valve will conduct and the anode voltage will fall, causing the grid voltage of V4 to fall also and cutting off that valve. As the signal being fed to V3 reaches its peak and starts to return to zero, the grid of V3 becomes less positive and so the valve cuts off. The anode now will have returned to a higher

*See Appendix 1

Fig. 4. Pulse generator



R1	470 kΩ	R7	100 kΩ	R13	33 kΩ	R19	500 kΩ	R25	4·7 kΩ	C4	1000 pF
R2	1 MΩ	R8	10 kΩ	R14	100 kΩ	R20	100 kΩ	R26	5 kΩ	C5	200 pF
R3	100 kΩ	R9	33 kΩ	R15	47 kΩ	R21	100 kΩ	R27	680 kΩ	C6	2000 pF
R4	1 kΩ	R10	10 kΩ	R16	47 kΩ	R22	1·5 MΩ	C1	0·1 μF	C7	0·1 μF
R5	33 kΩ	R11	33 kΩ	R17	4·7 kΩ	R23	500 kΩ	C2	0·1 μF	C8	0·1 μF
R6	50 kΩ	R12	680 kΩ	R18	0·5 MΩ	R24	10 kΩ	C3	1000 pF	C9	0·1 μF

positive potential and therefore the grid of V4 will be positive, allowing that valve to return to a state of conduction. It can be seen that, as the cathode of V4 goes negative, the grid of V4 goes positive and vice versa. This helps in producing a fast transition time and effectively produces a square wave output at the anode of V4. The output pulse is approximately the same length as the input pulse but some backlash does occur because the positive potential required on the grid of V3 to turn on the valve is not the same level as that required to cut the valve off. As the function of this part of the circuit is to produce a fast rising waveform, this error does not introduce any undesirable effects. The condenser C3 is included in order to pass the steep wavefronts of the signal between V3 and V4 without attenuation.

The output pulse from V4 is fed to C4 R13 which form a simple differentiating circuit. In order to have only a positive pulse applied to the grid of V5, the negative part of the differentiation is passed to earth through the diode D1.

(c) *Kipp Relay*[3, 4]

This is also a form of cathode-coupled multivibrator, but having only one stable configuration. In this circuit V6 is conducting, thus raising the common cathode voltage which is sufficient to keep V5 cut off. If a positive pulse is applied to the grid of V5 (or a negative pulse to its anode) the grid of V6 becomes negative, cutting off V6 for a period of time determined by C5 R19. If R19 is large compared with R15, the recharging time of C5 is much less than the time constant C5 R19. Thus, the recovery time of the circuit is small and allows a second trigger pulse to be applied shortly after the output pulse has finished. In order to have a wide range of pulse lengths, two coupling condensers, C5 and C6, were included; either of these may be selected by SW2. The values of these condensers were chosen in order to give a range of pulse lengths from 10 μsec to 1 msec when used in the time constant circuit C5 R19 or C6 R19. To allow calibration of this *CR* network, a pre-set resistor was connected in series with R19, its value being 20% of R19.

The method of displaying the pulse length on a meter is simply to have a resistor R23 the same value as R19 and both ganged so that R23 varies as R19. If a meter is now connected across R23 and made to read the voltage drop across it due to the bleeder network R18, R20 and R23, it can be seen that

(a) the meter is directly proportional to R23 (V=IR)
(b) the pulse length is directly proportional to R19 (t=CR)
(c) R19=R23
(d) the values of C5 and C6, and the current through R23, are constant, and
(e) the meter reading V will be proportional to pulse length.

The resistor R is pre-set to allow the meter to read full scale for voltage drop across R23.

(d) *Output Pulse Amplifier*

A CV2127 pentode was used as a conventional *RC* coupled amplifier to produce a negative output pulse. Over the range of pulse lengths amplified in this stage the screen decoupling condenser C9 was found to have no effect on the pulse shape. The output from the instrument is taken through a blocking condenser C8. This pulse is applied to the cathode of a c.r.t. to cut off the beam current.

A block diagram is shown in Fig. 5.

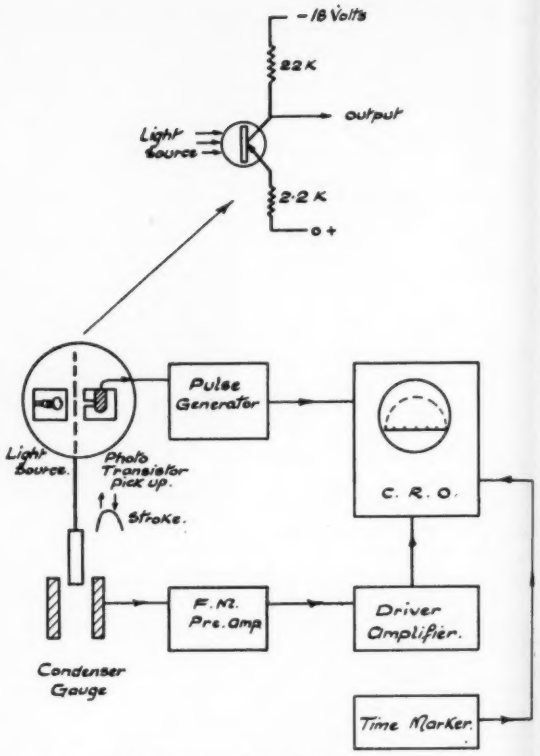


Fig. 5. Block diagram of apparatus

Applications

Photo-transistor Pick-up Unit

The instrument could be used where an accurate and continuous record of the variation of any quantity with displacement was required, being particularly useful where displacement time was not constant.

Where a continuous record of displacement was not required or the instrumentation not available, the transistor unit would enable spot readings to be recorded at specific intervals of displacement.

Other possible applications are for overload devices, in the automation field for programming of tool and ram travels, etc., where mechanical means are to be avoided.

Pulse Generator

It may be readily seen that many uses exist for a pulse generator of this type. Its uses in timing pulses or generating time intervals are of great use in oscillographic practice where it may also be used to trigger time bases after a known interval. The positive and negative signals can either blank out a c.r.o. beam or brighten the beam. If used with pick-ups such as the photo-transistor, one pulse may be fed to a counter

giving a digital display of time and distance. It is hoped to develop a magnetic pick-up to use with the pulse generator to determine deceleration of tup speed in drop hammers, etc.

Acknowledgements

The authors acknowledge the help of Mr. R. Munro, of the workshop staff, and also the interest of Mr. H. Ll. D. Pugh, Head of Plasticity Division. The work has been carried out as part of the research programme of the National Engineering Laboratory of the Department of Scientific and Industrial Research. The paper is published by permission of the Director.

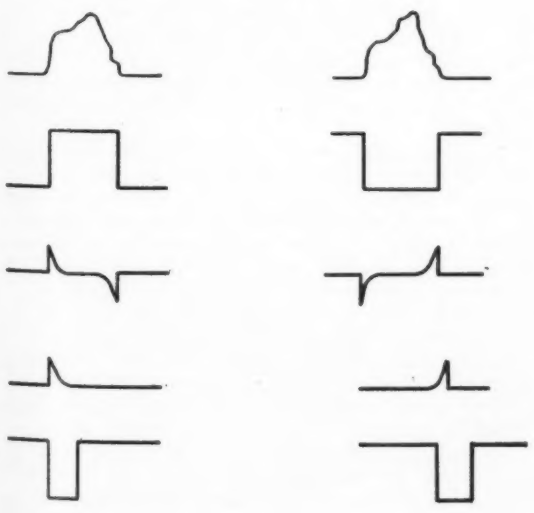
References

1. Watkins, M. T. and McKenzie, J. Cold extrusion of metals (VI)—under impact conditions. *M.E.R.L. Plasticity Division Report No.* 138, 1957.
2. Watkins, M. T., Ashcroft, K. and McKenzie, J. The slow extrusion of metals. *M.E.R.L. Plasticity Report No.* 111, 1956.
3. Levell, D. A. Pulse and time base generators. Pitman.
4. Puckle, O. S. Time bases. Chapman and Hall.
5. Amos, S. W. and Birkenshaw, D. C. *Television Engineering*, Vol. 3. Iliffe and Son.
6. Chance, B. Waveforms. *Radiation Lab. Series*, Vol. 19. McGraw-Hill.

Appendix I

It has already been indicated that, in the Schmitt trigger, two stable configurations exist, i.e., with V3 on and V4 cut off and with V3 cut off and V4 conducting. However, it was found that if V3 was allowed to conduct slightly the negative signals could also be fed to it to produce a negative output pulse; at the same time, positive signals would produce a positive output pulse. It can be seen that this would allow an output pulse to be triggered from the back edge of an input signal. If the input is made negative by selecting the input polarity to V2, the positive pulse fed to V5 will be the back edge of the differentiation due to C4, R13 and the diode D1. Thus, any pulse can be triggered from either the front or back edge of any input pulse. A waveform diagram of this is shown in Fig. 6.

Fig. 6. *Pulse generator wave forms*



BOOK REVIEW

A Simplified Technique of Control System Engineering. *By G. K. Tucker and D. M. Wills.* (*Minneapolis-Honeywell Regulator Co. Ltd.*) *Available from Honeywell Brown Ltd., Perivale.* 36s.0*d*. 1958. 303 *pp*.

A lecturer I knew used to remark that the human eye is very good at critically examining curves. The authors of this volume obviously subscribe to the same belief.

In their work as applications engineers with the Minneapolis-Honeywell Company, they have been impressed with the need for a simple approach to the problem of analysing a control system and adjusting the controllers for optimum results. The method they have adopted, and developed in this book, succeeds in avoiding any mathematics other than simple arithmetic and concentrates on purely graphical solutions. A basic knowledge of process instrumentation is all that the reader is assumed to possess.

A process under examination is split into blocks representing the various simple transfer functions and the response of each to a step input is discussed in conjunction with the type of recorder chart trace obtained. This is followed by a simple explanation of the three main control actions.

Frequency response analysis is next introduced and the graphical method of combining individual characteristics to obtain overall response demonstrated.

These principles are applied to the evaluation of system performance and, finally, to the analysis of plant and controller characteristics. This section is detailed in the extreme and the authors avoid the trap of quoting typical constants without any indication of whence they were obtained. The authors are at pains to indicate either exactly how to obtain the figures necessary, or what sources of reference to consult. They also include "memory joggers" to ensure that the reader does not overlook any items in his own analyses which may be absent from the example quoted.

The "text" section of the book concludes with a discussion of the shortcomings of frequency response methods in general and this simplified approach in particular. There follows, however, a series of twelve appendices which, in fact, occupy about a third of the book. These include a good bibliography, a lengthy glossary (useful, since a number of terms used are not very familiar) and various hints, tips, and elaborations based on the material in the chapters. It is a pity that no index is included.

The style and layout of the text is informal and based on the technique of splitting the subject into small sections, each one of which represents a step in the development of the argument. Each chapter is prefaced by a short definition of the coming discussion.

It is difficult to decide exactly for which class of reader the authors have written their book. It would probably be of most use to the instrument technician who wishes to obtain a basic grounding in control dynamics without having to learn the jargon of the mathematician. On the other hand, it will be invaluable to the manager who wants to acquire a closer insight into the technicalities of plant control than his administrative duties usually allow, particularly if he suspects that he is being "blinded with science".

C. B. FLINDT

Trends and Developments in Instrumentation in the U.S.A.

By A. J. MADDOCK, D.Sc., F.Inst.P., M.I.E.E.
Deputy Director of Research,
British Scientific Instrument Research Association

During the latter part of 1958 and the beginning of 1959 the author spent nearly five months in the United States of America studying instrument developments and the trends that instrumentation is taking, particularly in regard to control applications.

1. Introduction

IN view of the diversity of interests in the instrument industry, contact was made not only with instrument manufacturing concerns but also with those organisations which make considerable use of instruments and where continuously operating controls would be in use. In addition, visits to several research establishments were made and also to a number of the groups of large engineering consultant and contracting organisations.

From the extensive field of the instrument world it was obviously necessary to make a very limited selection which was hoped would be representative. The largest number seen was on the manufacturing side and these were divided into manufacturers of electronic, optical, electro-optical, mechanical, and physical types of instrument. The user group was divided into different industries and those chosen were oil, chemical, steel, and electronically-controlled machine tools. Research establishments covered government, university and sponsored concerns. The consultant and contractor group covered those engaged in varied interests. In all nearly 70 establishments were visited.

The sections which follow have been selected as showing trends and developments that are taking place in control systems, data logging and processing, and in computer control, all three of which are closely related.

2. Control Systems

All the major instrument firms producing control apparatus, the user industries and the contracting firms visited wished to discuss the relative merits of pneumatic and electrical (electronic) control systems and to give their views on the trend in this field.

Up to the present, pneumatic—and some hydraulic—controllers have occupied the major position in control systems and only two firms have had electronic controllers on the market, and some large installations have used their products. It is interesting to note that it was not until the Instrument Society Exhibition, held in September, 1958, that the other major control firms came out with electronic systems. At that show four other companies all produced for first view the results of their recent development efforts. None of these products is yet on the market and will not be so until the middle of 1959, so no user company has yet had an opportunity to try out any of these for his own assessment. Considerable interest was shown in these at the show and they probably ranked highest in interest value.

None has worked to any common output either from the transmitters or controllers that would make for compatibility between systems, but each has adopted its own standard signal which it keeps throughout its system. However, there is one common feature and that is that generally the "zero" for the system is uplifted above true zero and a 1 : 5 ratio of output current or voltage is used to cover the full range of output: this is comparable to the existing pneumatic systems which all operate over the range 3-15 p.s.i. The outputs of these several units are:

10-50 mA d.c. final, 0·4-2 mA intermediate stages (1 system)
4-20 mA d.c. (1 system)
1-5 mA d.c. (4 systems).

A discussion on the considerations underlying the

design and system of working of one of the new equipments was described at the I.S.A. Conference. Without going into too much detail, the following main points were adopted:

(1) Modular design—division into transmitters (or converters, to which is attached the detecting element), recorder (and indicator), controller, regulator.

(2) Signal output—outputs from all transmitters and controllers to be d.c., avoiding interference and phasing difficulties. Main outputs to be 10-50 mA corresponding to zero to full output. The set-up zero level aids in calibration and allows reserve power for actuation of alarm relays and fail-safe systems.
Intermediate output before final amplifier stage set as 0·4-2 mA.

(3) Common calibration—each unit is factory calibrated to work over the above fixed current ranges, thus ensuring interchangeability of units and ready possibility of cascading elements.

(4) No valves—silicon transistors, Zener diodes (for reference and stabilising purposes) and magnetic amplifiers to be used throughout.

(5) Recorder and controller—kept entirely separate functionally (though they may be housed in one case if desired) this being of advantage if data logging takes complete precedence and no recorders are installed.

These latest companies have endeavoured to depart from the use of valves in the circuits, but some have not been able to eliminate them entirely. One of these firms employs transistors and magnetic amplifiers and uses a voltage-variable capacitor as the inverting device to change from d.c. to a.c. in the amplifier employed with thermocouples.

Another firm uses transistors, but needs one valve: a third also uses transistors, but needs some valves in the controller to obtain long time-constants: the fourth uses a number of valves. Some of these companies have made sure that they have a complete system available with the necessary transmitter units, converters, etc. All use electrical-pneumatic converters at the output to operate a final regulating valve. Several of the input transducer units, however, bear signs of carrying over from earlier days, since they convert to a mechanical movement and thence to an electrical signal. Ideally direct conversion to an electrical signal is desirable.

Generally speaking, all are agreed that both pneumatic and electrical systems will be in use, at least for some time to come, and much will depend upon the conditions of use as to which is used. Pneumatic systems have the merit of being easily understandable and easy to maintain, and initial cost of the instrument units is cheaper. Also they are very good for hazardous situations in a plant where an electrical system would need full protection of an explosion-proof nature. At present this is mandatory as laid down by the fire underwriters, but considerable interest is being shown in British efforts to devise systems which are intrinsically safe and to get them accepted by industry. A pneumatic system might well also be favoured by the user who wishes to extend an existing system or by a small company who only needed to install a single instrument.

Electronic systems are valuable where speed of response is desired or where there are long runs between transmitter and control room. One contractor, however, considers that the greatest merit is the elimination of hysteresis (since there are no moving parts) and removal of its bad effect on derivative control. A further advantage is that when data logging or computing systems are employed, the standard input signal required by these is an electrical one, and their output is also electrical so that it is obviously advantageous to use an all-electrical system throughout. An appropriate electrical regulating valve, which would have characteristics similar to a pneumatic regulator valve, is still desired as conversion is needed at this point. One of the companies manufacturing control gear brought out at the show—and considered by many to be the "cutest" idea of the show—a thermoregulator valve which operates directly from an electrical signal to cause evaporation of freon in the system and create a gas pressure to operate the valve diaphragm: condensation is needed in another part of the circuit and considerable static power must be provided—e.g., 400 W heating power for an effective output power of under 1 watt. It is too early to report on applications of this device.

Some of the large consulting and contracting firms do not yet feel they can recommend to their customers adoption of the electronic system until more have been tried, but they are only too pleased when a customer expresses a desire to install such a system: this gives both contractor and customer the opportunity to gain experience with the system. Construction of several new plants using these electronic controllers is under way.

A gradual change to electronic systems is foreseen in most places for many new plants, but pneumatic systems will continue to be used in many situations.

3. Data Logging and Processing

All the major instrument companies and the large user concerns are actively engaged in developments concerned with recording data and, in some cases, processing it: this is considered to be the main trend in instrumentation for the immediate future. A study of the technical details of the systems being employed was not made, but rather the general trends and what is required of such systems was noted.

In the simplest cases a different method of recording data than is currently used in chart recorders is desired. This is mainly to reduce the storage of a multiplicity of records, many of which only contain steady-state information. The general desire now is for the data logging system to survey the output from all sensing elements in the plant at short, periodic intervals and compare their outputs against previously determined set values: any deviation outside the limits set is to be typed out on an electric typewriter and in some cases an alarm sounded. Additionally, a complete record of the values of all detecting points is typed out at, say, hourly or half-hourly intervals.

Generally speaking, no system is yet arranged to have a "memory" incorporated whereby the lead-up to a

faulty condition which might occur between the fully recorded (½ or 1 hour) times could be studied. Some thought, however, is being given to this and a loop of magnetic tape, or magnetic drum, seem to be the most favoured possibilities.

Other concerns require more elaborate information to be prepared and incorporate some simple computing units to process some of the data. An example is to determine the steam raising efficiency of a power station or to carry out the monetary accounting to determine the actual cost of production on a continuous basis. This latter was one of the features that one of the oil companies would like to see, but it is thought that the electronic systems are not yet reliable enough for this class of work, particularly when corrections would have to be made within the system to the direct records obtained of flow, temperature, etc.: systems using solid-state devices might be capable of the required accuracy and reliability. The large steel mills producing tinplate in coiled form now operate data reduction systems so that all essential information, such as thickness, coating weight, pinholes per unit area, etc., are printed on a label attached to each coil. This has occurred in the canning industry, one of the largest users of tinplate: whereas previously they took all material in cropped sheet form, now they operate only with continuous feed machines using coils of the material.

Additional comments from several concerns, manufacturer or user, may be given briefly as follows:

One company has installed one of the largest units for data logging in the country. It has been in operation for about two years at an oil refinery: this is the largest single-unit refinery plant in the U.S.A. to be constructed at one time and has an input of 130,000 barrels of crude oil per day. Thirteen unit scanners are installed, each sampling up to 400 input points: in all there are nine control rooms located in different parts of the plant.

It is of interest to note that control of this refinery (put into service nearly two years ago) is entirely pneumatic. Analogue-digital conversion is carried out for operating the print-out typewriters and for punching computer tape for subsequent processing on throughput, efficiency, costing, etc. Sampling rate is 1 per sec.

One power station installation began operation in September, 1958, and two others are under construction. These sample 400 points at a rate of 5 per sec. The system integrates from the records and computes the heat rate (i.e., efficiency of the boiler system—lb steam/lb fuel). The next step in future installations, when more computational work is done, would be to compute the ideal heat rate possible for a given fuel, load and ambient conditions, and also the actual rates as above and compare the two so that indication would be given of how far off the ideal the station is working.

A large chemical concern has three plants with analogue-digital converters sensing 300 points, the results being coded on to teletype paper for typing out. The present aim of this company is to collect all data on these plants to help them in future instrumentation and possible addition of computer control: they are therefore logging all the information and not just deviations outside limits.

In another system operating on 100 points, in addition to the actual readings of all points being typed out every hour, the following data is typed at the start of a process, when originally set up:

(i) the values that all points should have
(ii) the control values as set by the operator
(iii) the actual values of the process.

This is helpful to the operator, the supervisor and the company generally.

A cheaper system, known as the scanning or comparator system, compares the actual process values regularly with the values they should have, as imprinted on a magnetic tape: deviations sound the alarm and start recording.

Possible extension of data logging systems to accurate gauging systems for storage of information, statistical analysis, quality control and sampling, was mentioned.

Another manufacturer who is developing data logging systems has been anxious to ensure that these are reliable. Several first models are in use at large user concerns handling 400 or 1,000 inputs. They operate completely with solid-state devices: they have been in use for one year and reports are now coming in on their serviceability and general behaviour under plant conditions.

4. Computer Control

Although computer control of process plants has been mooted for many years, there has been considerable hesitancy to apply such methods: up to the present (March, 1959) there is no plant in the U.S.A. which is computer controlled. Much of the hesitancy may have been due to electronic equipment generally, and computer equipment particularly, not being considered sufficiently reliable. This was mentioned particularly and it was thought that computers had suffered a setback since several firms tried to get in too early immediately after the war and the units were not sufficiently reliable. The adoption of computer control is now following a more cautious approach and the data reduction systems (see Section 3) now being developed and installed point the way to reliable equipment and to much of the apparatus that would be required in any control system.

This is the way that most concerns are approaching this goal, i.e., to install first of all good data logging systems, which would be almost a pre-requisite of at least a large part of a computer system, especially in the sampling equipment. Careful analysis of the plant behaviour is also necessary and data accumulated in this way is helpful in understanding this: additionally, proper plant analysis must be carried out to determine full operating conditions and obtain the necessary mathematical expressions before any system of control can be devised.

The cost of the equipment is very high and figures of $300,000 were quoted so that economic justification needs to be made so that the equipment will pay for itself. An improvement in efficiency of from 1-5%, with an average of around 2½%, might be considered worthwhile if the throughput of the plant is large enough. The first computer control system was just being installed at the period of the visit and this is at an oil company. It will, therefore, be some time before

any results are available to see how this system works out and other instrument manufacturers and large user concerns are all interested in seeing how this installation behaves. Another installation is on order for a cement making company.

This particular computer equipment has been specially designed for process control work. It is fully transistorised and occupies a cabinet 36 in. high × 56 in. long × 29 in. deep with power requirement of 500 W. It has an associated analogue-digital converter to accept signals from 0 to 10·23 V d.c. from up to 1,024 points. A magnetic drum is used for storage in the computer with 7,963 words. The price of the computer alone is $98,000 and of the converter about $50,000, depending on complexity, so that a complete installation of control with associated instruments and engineering might cost $250,000.

Whilst power station companies might spread their recovery of the above cost over five years, it is the practice in the oil and chemical industries to reckon on not more than two years, so that at least $125,000 must be produced as "savings" in the process each year. These may be in the form of increased product value, or of reduced raw material quantities, or reduced operating costs, the latter being the most difficult to achieve, especially in these two industries where personnel are already at minimum level. Taking the efficiency improvement as 2½% means that such a system can only be considered when the product value is around $5 M per annum and correspondingly less if improvement is higher.

A cost recovery period of two years and expected improvements of 1-5% were confirmed at several places. Firms who have installed large data logging systems, as for example is noted in Section 3 above, are turning towards developing full computer control, and it is expected that this method of working will begin to come in more rapidly in 1960 and onwards.

Whilst improvements of the order of 2½% are expected by the addition of computer control, there are chemical engineers and others who say that existing chemical plants could be improved by the same amount if their processes were examined carefully—indeed for the purpose of considering control they must be so analysed —and so the same improvement could be obtained without the very costly computer equipment. Some think that a computer could be better employed in a factory manufacturing piece parts, to be used for costing, billing, checking, etc., and that several percent improvement should be obtained in this way.

In all places where these proposals were discussed it was agreed that the computer would not be allowed absolute control of the plant. It would, in fact, operate by varying the set-points of all the individual controllers each with their own local loop control on, say, temperature, flow, level, etc. Thus any failure in the computer would not throw the whole process out of action: this would continue as at present through the individual control elements.

Some of the large consultants and contractors are hesitant and are not yet recommending computer control to their customers: they prefer to go first to data logging systems and later to computers. One even considers that more interlocks are needed in power station work, especially on the steam raising side, and these must be satisfactorily dealt with first. However, another firm of this nature is considering possible application to a pipeline delivering gas from sources up to 1,000 miles away: it is particularly desired to relate the operation of the far booster pumps in readiness for the near-end demand for gas several days later.

One of the large oil companies has had a pilot plant built by an instrument manufacturer which is fully instrumented and with computer control so that they may study, in miniature, the behaviour of an oil-cracking plant. The computer controls the set-points of the several individual controllers.

A large engineering organisation has been working on optimising schemes or control by automatic experimentation. Such computer control has been fitted to a pilot plant for a chemical company and another one is being built for an oil company. This scheme works on the basis of sensing the output controlled quantity and, if any deviation occurs, determining whether a small change in all the variables, considered one at a time, results in a change of the output towards or away from the desired value: the process is continually repeated until each is brought to equality with the desired value.

Acknowledgement

The tour of the United States was carried out on behalf of the Department of Scientific and Industrial Research and thanks are due to them for permission to publish some of the results.

Noise Measurement

THE quietness of machines to be used in the home or the hospital has for long been an important sales factor. Noise reduction in other types of machines is also important, particularly in machine tools which are to be exported to countries whose laws lay down maximum permissible noise levels.

There is very little information available about the noise produced by everyday mechanisms like gears and ball-bearings, and the way it is related to the dimensional accuracy of the components. This problem is being investigated at the National Engineering Research Laboratory to find out whether it is possible to produce quiet mechanisms more economically than at present.

Noise measuring equipment and special test facilities have been provided for these researches. The Laboratory is also willing to use them to advise firms on the reduction of mechanical noise in their products or works. A mobile laboratory is used for measuring noist on site; an anechoic chamber is available at Ease Kilbride for measuring noise from office machinery and other relatively quiet equipment, or for measuring the directional properties of noise from machines. The Laboratory is also willing to advise firms on techniques for inspecting products for noise.

Facilities are available for calibrating microphones and associated noise measuring equipment over a frequency range from 30 to 8,000 c/s. Vibration transducers can be calibrated up to 5,000 c/s.

A fee is charged for advisory work on noise reduction if measurements are necessary.

Theoretical Models of Pneumatic Control Apparatus

By R. JACKSON, M.A.

Imperial Chemical Industries, Billingham Division

1. Introduction

Although pneumatic measurement and control devices have been used increasingly in the petroleum and chemical industries since about the time of the First World War, papers devoted to the theoretical analysis of their behaviour have only appeared during the last 10 years or so.

A good summary of the earlier work on this subject and its application to commercially available pneumatic controllers can be found in chapters 11 and 12 of the well-known book by Young[8], but work which has appeared in the last four years or so has not yet been summarised. It is the object of this paper to review these developments and to show how they modify the simple picture presented by Rutherford and Aikman[3, 4], and by Farrington[1].

It is, of course, impossible for any pneumatic device to produce an output pressure which varies exactly as a multiple of the input, because of unavoidable lags and non-linearities in the operation of the pneumatic circuit and associated mechanical components. On the other hand, in the case of controllers, relatively large and adjustable lags are purposely introduced in order to modify the dynamical behaviour of the system in a useful manner; the author[11] has distinguished these cases by referring to them as "inherent" and "imposed" properties of the system respectively. The papers which appeared up to the time of the publication of Young's book dealt primarily with imposed dynamical effects in pneumatic controllers, while subsequent work has investigated the effects of inherent static and dynamic properties of the system on its behaviour. The same sequence will be followed here, dealing with the original simple model of a controller in Section 2 and going on to discuss inherent effects in Sections 3 and 4. Finally, in Section 5, one or two problems still lacking a satisfactory theoretical treatment will be described.

2. The Simple Model

As there are considerable differences in detailed arrangement between the various pneumatic controllers at present on the market the most satisfactory approach is to treat one typical and fairly common arrangement in detail. The treatment given here is very similar to that of Rutherford and Aikman[4] and the system analysed belongs to their "Type II". For a corresponding treatment of other common arrangements the reader should consult Rutherford and Aikman's paper.

Consider the system shown in Fig. 1, which represents schematically a force-balance controller. The pressures p_m and p_d represent the measured and desired values, and as a result of their difference a couple proportional to the product of $p_m - p_d$, the effective cross-sectional area of the bellows and the distance a from pivot P, is exerted on the flapper system F. This couple is opposed by an opposite couple applied by the second pair of bellows, proportional to the product of their cross-sectional area, the distance b and the pressure difference $p_f - p_i$. Any difference between the moments of these couples causes a deflection of F which is inversely proportional to the combined spring stiffness of the bellows and any other springs attached to it. Very small movements of F above the nozzle N (of the order of one or two thousandths of an inch) cause the pressure between N and the restrictor R to vary between a value approaching the supply pressure and a value little above atmospheric pressure. These pressure fluctuations are transmitted to the load through a pneumatic relay, the details of which may be neglected for the moment, and are fed back to the bellows I and F through the adjustable restrictors R_I and R_D. The controller is normally set up so that the output pressure is 9 p.s.i. when $p_m = p_d$ and $p_i = p_f$, so it will be convenient throughout, unless otherwise stated, to measure all pressures from this value as origin.

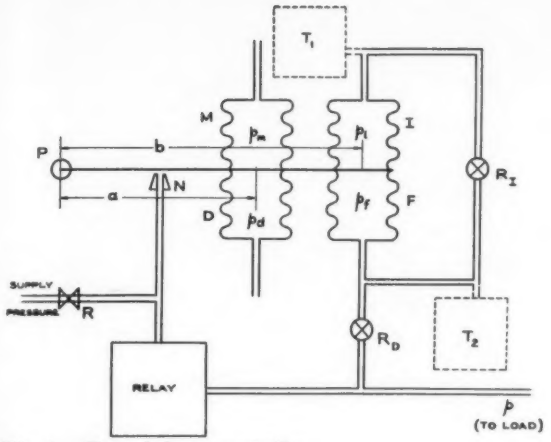


Fig. 1. Force-balance controller

The simple model treated in this section is characterised by the following assumptions:

(a) The flapper-nozzle system and relay act as a perfect high gain amplifier, giving an output pressure p proportional to displacements of the flapper and following these displacements without time lag.

(b) The mass flows of gas through restrictors R_D and R_I are proportional to the pressure differences across them.

(c) Changes in volume of the bellows as the flapper moves are negligible fractions of their total volumes, and pressure variations in the bellows can be treated by the ideal gas laws assuming isothermal conditions to hold throughout.

With these assumptions the following equations for the pressures can be written down immediately:

$$p = K\,[a(p_m - p_d) - b(p_f - p_i)] \quad \ldots\ldots\ldots \quad (1)$$

$$V_f \frac{dp_f}{dt} = \frac{1}{r_d}(p - p_f) - \frac{1}{r_i}(p_f - p_i) \quad \ldots\ldots\ldots \quad (2)$$

$$V_i \frac{dp_i}{dt} = \frac{1}{r_i}(p_f - p_i) \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where K is a gain constant involving the distance between P and N and the gain characteristics of the flapper-nozzle and relay, V_f and V_i are the total volumes associated with the bellows F and I respectively, and r_d and r_i are proportional to the resistances to flow offered by restrictors R_D and R_I. The bellows I and F are assumed to be identical, but for generality, capacities T_1 and T_2 may be assumed to be connected to them, so that $V_f \neq V_i$ necessarily. p_f and p_i can most simply be eliminated from (1), (2) and (3) after taking Laplace transforms, giving

$$\frac{p}{K} = a(p_m - p_d) - \frac{br_iV_is \cdot p}{\left[\left(r_dV_fs + 1 + \frac{r_d}{r_i}\right)(r_iV_is + 1) - \frac{r_d}{r_i}\right]} \quad (4)$$

Now K is a large gain, so provided b is not too small the left hand side of this should be negligible compared with the second term on the right hand side, and we have approximately

$$p \simeq \frac{a}{b}(p_m - p_d)\left[\left(1 + \frac{r_d}{r_i} + \frac{r_dV_f}{r_iV_i}\right) + r_dV_fs + \frac{1}{r_iV_is}\right] \quad (5)$$

which should be compared with the standard form of the equation for the response of a proportional plus derivative plus integral controller

$$p = \mu\left[1 + T_ds + \frac{1}{T_is}\right](p_m - p_d) \quad \ldots\ldots\ldots \quad (6)$$

where μ is the proportional gain, T_d and T_i the derivative and integral action times respectively. Comparing coefficients in (5) and (6) gives

$$\mu = \frac{a}{b}\left(1 + \frac{r_d}{r_i} + \frac{r_dV_f}{r_iV_i}\right). \quad \ldots\ldots\ldots\ldots \quad (7)$$

$$T_d = \frac{r_dV_f}{\left(1 + \frac{r_d}{r_i} + \frac{r_dV_f}{r_iV_i}\right)} \quad \ldots\ldots\ldots\ldots \quad (8)$$

$$T_i = r_iV_i\left(1 + \frac{r_d}{r_i} + \frac{r_dV_f}{r_iV_i}\right) \quad \ldots\ldots\ldots\ldots \quad (9)$$

In calibrating the integral and derivative restrictors in terms of integral and derivative action times, the system is arranged as a two-action controller, in accordance with the British Standard definitions of derivative and integral action times[12]. In the derivative calibration, R_I is closed, so $r_i = \infty$ and (8) gives

$$T_d = r_dV_f = \tau_d$$

where we denote by τ_d the calibrated value of the derivative action time. Similarly $r_d = 0$ for the calibration of the integral action time, so

$$T_i = r_iV_i = \tau_i$$

Expressing (7), (8) and (9) in terms of the calibrated action times and the volumes V_f and V_i then gives

$$\mu = \frac{a}{b}\left[1 + \frac{\tau_d}{\tau_i}\left(1 + \frac{V_i}{V_f}\right)\right] \quad \ldots\ldots\ldots\ldots \quad (10)$$

$$T_d = \frac{\tau_d}{\left[1 + \frac{\tau_d}{\tau_i}\left(1 + \frac{V_i}{V_f}\right)\right]} \quad \ldots\ldots\ldots\ldots \quad (11)$$

$$T_i = \tau_i\left[1 + \frac{\tau_d}{\tau_i}\left(1 + \frac{V_i}{V_f}\right)\right] \quad \ldots\ldots\ldots\ldots \quad (12)$$

so in a 3-action controller the gain and action times are not equal to the calibrated values. Adjustment of the derivative or integral restrictor affects all three effective actions, so the adjustments are said to interact, and the factor $\left[1 + \frac{\tau_d}{\tau_i}\left(1 + \frac{V_i}{V_f}\right)\right]$, which appears in all the above expressions, is known as the interaction factor. The first published account of this effect appears to be due to Farrington[1] who treated the special case $V_i = V_f$ of the system just analysed, and a second arrangement in which the derivative and integral restrictors are connected in parallel rather than in series. A further discussion is given by Janssen[5], and the form of the interaction factor has been systematically derived for most of the common arrangements by Rutherford and Aikman[4], whose paper should be consulted for further details.

The presence of interaction in a controller is objectionable for two reasons. Firstly, most methods of adjusting a controller for optimum operation in a given loop depend on successive adjustments of the

true gain and the true derivative and integral actions. The presence of interaction can therefore cause considerable confusion since it is not possible to adjust these quantities independently. This objection is perhaps not so important as would appear at first sight since in practice controllers are usually set up more or less empirically on the basis of previous experience rather than by following a fixed procedure, but there is a second effect of interaction which is more fundamental. Suppose we attempt to solve (10), (11) and (12) for the values of $\frac{a}{b}$, τ_d and τ_i which would give specified values of μ, T_d and T_i. Typically we obtain expressions of the form

$$\tau_i = \frac{T_i}{2}\left\{1-\sqrt{1-\frac{4\xi T_d}{T_i}}\right\} \quad \ldots\ldots\ldots (13)$$

where $\xi = 1+\frac{V_i}{V_f}$. It is seen that there is no real value of τ_i which satifies this if $\frac{4\xi T_d}{T_i} > 1$, i.e., if $T_d > \frac{T_i}{4\xi}$. Values of the true controller parameters satisfying this inequality are therefore not attainable with the interacting system; in fact, the attainable settings are limited to the interior of a "wedge" when μ, T_i and T_d are plotted on rectangular axes, as shown by the shaded region in Fig. 2. This restriction of the effective amount of derivative action available may, in certain circumstances, limit the attainable control quality. With Rutherford and Aikman's method of setting up the controller, for instance, in which the integral action time is made equal to the natural period of oscillation of the control loop, it may be shown[4] that interaction limits the phase advance obtainable from the controller.

In addition to the basic assumptions (a), (b) and (c) of the simple model, equation (5) describing the controller's behaviour depends on the assumption that 1/K is very small compared with b, which will not be the case if b is reduced in an attempt to increase the overall gain as given by (7). In the limit when $b \rightarrow 0$ (4) becomes approximately

$$p \simeq Ka(p_m - p_d) \quad \ldots\ldots\ldots\ldots\ldots (14)$$

so at very narrow proportional bands the derivative and integral actions tend to be removed, and the gain tends to that of the flapper-nozzle system without feedback. Correspondingly, any non-linearities in the gain characteristic of the flapper-nozzle affect the overall gain characteristic of the controller. When b is larger, the original simplifying assumption leading to (5) is valid and the overall characteristic is unaffected by non-linearities in the flapper-nozzle characteristic. These effects of finite flapper-nozzle gain were briefly discussed by Janssen[5], Rutherford and Aikman[4] and Williamson[7]. Clearly they become less important as the flapper-nozzle gain becomes higher, and less objectionable as its characteristic becomes more closely linear. Methods of achieving higher gain and greater linearity from the flapper-nozzle are discussed very fully by Kirk[2].

Although the majority of pneumatic controllers are interacting, it is perfectly possible to generate the three actions in separate units and add them together in a pneumatic summing relay, thus obtaining a non-interacting system. The characteristics of one such system are described in detail by Williamson[7].

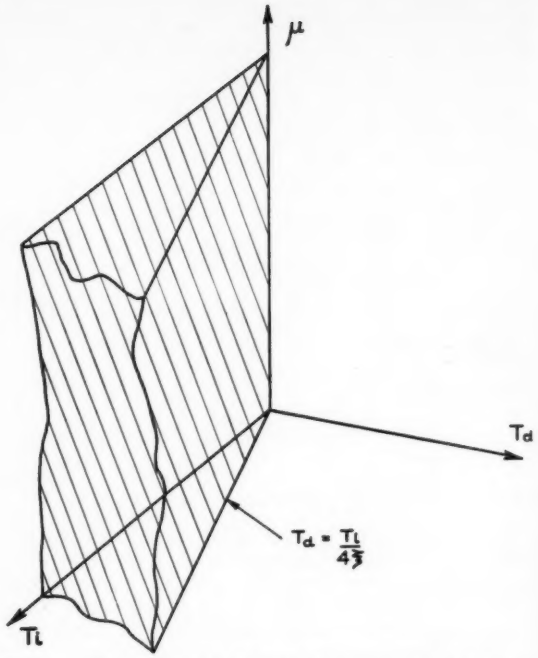


Fig. 2. The effect of interaction between controller terms

3. Effects of Static Deviations from the Simple Model

In this section the effects of relaxing assumptions (b) and (c) in the treatment of the simple model will be discussed, postponing the discussion of assumption (a) until Section 4. The most complete published investigation of the validity of assumptions (b) and (c) is due to Webb[6].

First considering assumption (b), it is well known that the flow of a compressible fluid through a restriction is not proportional to the pressure difference, and that the actual form of the relation depends on the type of restriction (orifice or tubular) and on the values of the upstream and downstream pressures. The derivative and integral restrictors most commonly take the form of tapered needle valves seating on conical seats, when Webb assumed that the equation for isothermal laminar flow was valid, giving

$$\text{Flow} = \text{constant} \times (p_1^2 - p_2^2)$$

where p_1 is the absolute upstream pressure and p_2 the absolute downstream pressure. The variations in pressure in a bellows on the downstream side of the restrictor therefore satisfy an equation of the form

$$V\frac{dp_2}{dt} = \frac{1}{r'}(p_1^2 - p_2^2) = \frac{1}{r'}(p_1+p_2)(p_1-p_2) \quad \ldots\ldots (15)$$

which is seen to take the same form as equation (3) for variations of pressure in the integral bellows if we write

$$\tau_i = r_i V_i = \frac{r'V}{(p_1+p_2)} \quad \ldots\ldots\ldots\ldots (16)$$

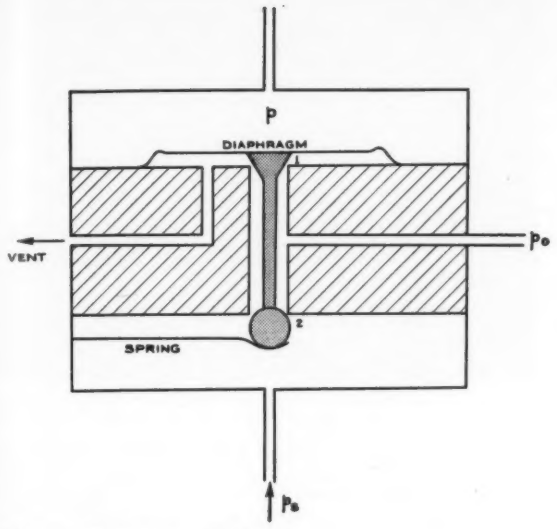


Fig. 3. Continuous bleed relay

Thus the calibrated integral action time, τ_i, is inversely proportional to (p_1+p_2), i.e. to the mean absolute pressure at the restrictor. Since this may vary between the limits 18 p.s.i. and 30 p.s.i. as the controller moves through its normal operating range, the integral and derivative action calibrations depend strongly on the point in the operating range at which the calibration is carried out. This could conceivably have serious effects if the control loop had been set up with a small margin of stability. As the pressures in the various chambers of the controller altered in the course of its operation, τ_i and τ_d would alter and consequently the interaction factor would alter, causing changes in μ, T_i and T_d which could shift the system over the stability boundary. This difficulty can be overcome by using an incompressible hydraulic fluid in part of the feedback system in place of air, since in this case the equation for isothermal laminar flow is

$$\text{Flow} = \text{constant} \times (p_1-p_2)$$

as assumed in the treatment of the simple model. This method has been used successfully by at least one manufacturer.

Turning now to assumption (c), it is not difficult to see that if the change in bellows volume is finite, the effective spring stiffness of the bellows increases with the pressure of the air trapped in it. This has no very serious consequences for the force balance controller which has been treated, since the only quantity in the performance equation (4) which depends on the spring stiffness of the bellows assembly is K, and provided this is large it has no effect on the behaviour of the system, which can be represented by the simplified equation (5). This is no longer true, however, for a motion balance system in which the differences between p_m and p_d, and between p_f and p_i are allowed to produce deflections, which are then subtracted by a system of linkages or some other mechanical arrangement. In this case the constants a and b in equation (4) effectively depend on the bellows stiffness, so an increase in p_i, for instance, will cause b to decrease and hence will reduce the proportional bandwidth. The force balance arrangement is therefore superior to the motion balance arrangement in static performance, as its behaviour is less dependent on the performance of the bellows. We shall see later, on the other hand, that the force balance arrangement may have certain disadvantages from the point of view of the dynamic performance.

4. Inherent Dynamical Effects

The consequences of assumption (a) for the simplified model are very far reaching. With this assumption a proportional controller would act as a perfect amplifying transmitter, while devices such as differential pressure cells would exhibit no dynamical effects which, of course, is far from a true description of the actual situation. Lags in the operation of the flapper-nozzle and relay of a controller were first included explicitly in the model by Gould and Smith[6], while a further treatment leading to a method of estimating the corresponding time constants was given by Westcott[10].

To analyse the operation of this part of the system more closely it is necessary to consider the operation of the pneumatic relay in greater detail. Fig. 3 shows one form of continuous bleed relay in which the input pressure p, acting on a diaphragm, moves a double seated pilot valve so as to connect the load at pressure p_L either to the air supply through port 2 or to an atmospheric vent through port 1. As p varies the ratio of the flow resistances at ports 1 and 2 changes and the system behaves like a pneumatic potentiometer connected between the air supply and atmospheric pressure. The name "continuous bleed" arises from the fact that there is a continuous leakage of air from the supply to the vent when the relay is in balance. The flapper-nozzle and relay connected in series form a system of two effective time constants, one arising from the capacity of the inlet chamber of the relay together with the parallel resistances of the nozzle and air restrictor R (Fig. 1), and the other from the capacity of the load connected to the relay output together with the parallel resistances at the pilot ports 1 and 2 (Fig. 3). In the absence of derivative or integral action the inherent dynamical behaviour of the controller is therefore assumed by Gould and Smith and by Westcott to be represented by a block diagram of the form shown in Fig. 4, where K_N represents the effective gain of the flapper-nozzle system and K_R the effective gain at the relay pilot valve, while τ_N and τ_L are the time constants just discussed. p_N and p_L are the pressures in the inlet chamber of the relay and in the load respectively.

The time constants τ_N and τ_L are not easily accessible to direct measurement and Westcott[10] has suggested a straightforward method of estimating them

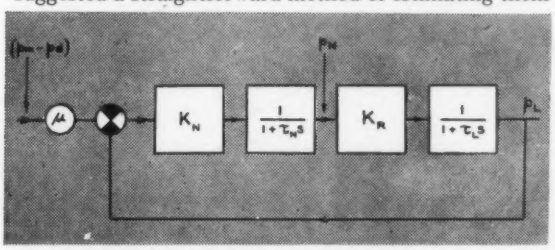


Fig. 4. Block diagram of a simple controller

from measurements of the attenuation of a sinusoidal variation in $(p_m - p_d)$ at various frequencies. This depends on the fact that the log gain-log frequency curve for a second order system with feedback exhibits a maximum as shown in Fig. 5. The two curves sketched correspond to different load volumes connected to the relay output; τ_L will, of course, take different values τ_{L1} and τ_{L2} for the two loads. Westcott gives simple formulae relating the gains and the time constants τ_N, τ_{L1}, and τ_{L2} to measurements of the gains G_0, G_1, G_2 and the frequencies ω_1 and ω_2 indicated in Fig. 5. His paper should be consulted for further details.

If a step change in $(p_m - p_d)$ is applied to the input of the controller the load pressure will not follow instantaneously, as would be the case with the simple model of Section 2, but will settle to its final value after some sort of transient. It would be possible to predict the form of this transient from the model shown in Fig. 4, obtaining a result of the form shown in Fig. 6 (a), where the overshoot y is proportional to the step amplitude Δp and the rise time T is constant. (This is characteristic of any linear model of the system.) When step responses of various amplitudes are actually measured, however, they are found to take the form shown in Fig. 6 (b) with the overshoot almost independent of the step amplitude, through a wide range of amplitudes, and the rise time roughly proportional to the step amplitude.

The author[11] recently pointed out that this anomalous behaviour is easily explained by noticing that the non-linear form of the flapper-nozzle and relay gain characteristics becomes very important when lags in the

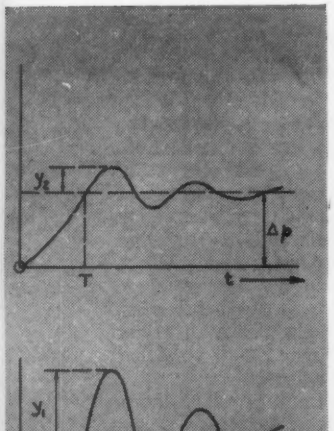


Fig. 6(a). Transient behaviour predicted by the linear theory

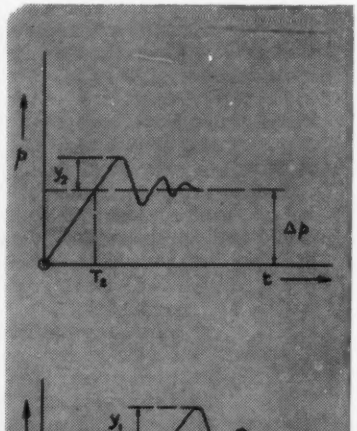


Fig. 6(b). Observed form of the transient behaviour

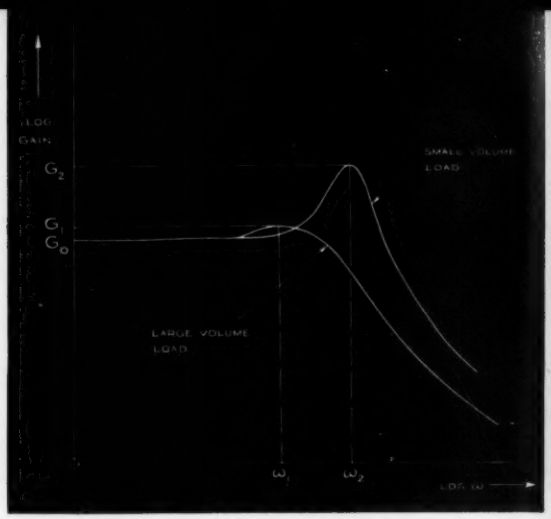


Fig. 5. Illustration of Westcott's method

feedback loop are taken into account. In a typical system the movement of the flapper above the nozzle required to change the equilibrium output pressure from one extreme end of its range to the other is only a few thousandths of an inch, so that an extremely small departure from the true force balance condition in the bellows attached to the flapper is sufficient to saturate the flapper-nozzle amplifier by blanking off the nozzle completely or allowing effectively free flow of air. The same is true, though usually to a rather smaller extent, for the gain characteristic of the relay. Thus a step increase in $(p_m - p_d)$ will force the flapper fully down on to the nozzle, from which position it will not rise until the pressure in the feedback bellows has risen very nearly to the value necessary to establish force balance. But in the case of a proportional controller connected by short lines to a fairly large volume load, such as a diaphragm valve motor, the feedback bellows is closely coupled to the load and its pressure cannot increase faster than the load pressure. The flapper therefore remains seated on the nozzle until the load pressure has increased to the new force balance condition, and the whole of the earlier parts of the transients shown in Fig. 6 (b) are described with the amplifying units saturated. Clearly, in these conditions, the model shown in Fig. 4 cannot represent the true behaviour of the system, but a good representation can be obtained quite simply by replacing the amplifiers K_N and K_L by pure switches, operating when the input pressure passes through 9 p.s.i., which connect the subsequent loads either to the air supply at pressure p_s or to an atmospheric vent. The curves of p_N and p_L as functions of time then consist of segments of exponential responses aiming at the supply pressure and atmospheric pressure alternately, with time constants τ_N and τ_L. p_N switches between these two segments when $bp_L = a(p_m - p_d)$, while p_L switches when p_N is equal to 9 p.s.i. Using these facts the transient can be very simply constructed as shown in Fig. 7. The effect of the finite widths of the linear bands of operation is to round off the peaks of this transient; a complete treatment taking account of the finite linear bands is given by the author[11].

The saturating behaviour just described is not of great importance in the normal operation of a properly designed controller, when all the input variations are fairly slow, but it finds important application in dealing

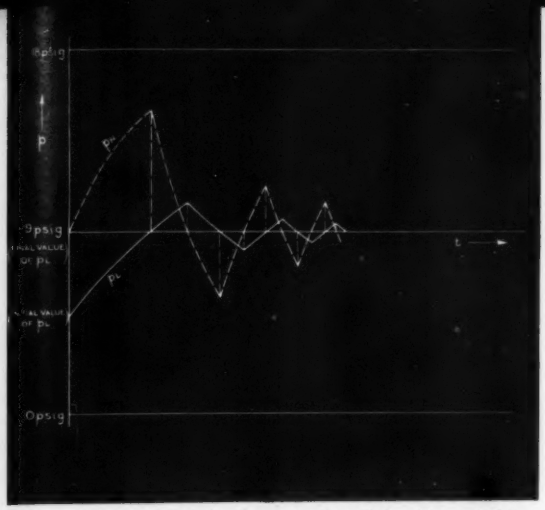


Fig. 7. Transient behaviour predicted by the switching approximation

theoretically with the rapid, large amplitude sustained oscillations known as "pumping" which are often troublesome in pneumatic systems. The speed and amplitude of these oscillations is such that the flapper-nozzle and relay spend very little time in their regions of linear operation, and a linearised theory is quite inappropriate to describe them. The author[11] has shown that the switching approximation just described is capable of giving a very good account of this phenomenon in a system consisting of a valve motor driven by a valve positioner, with a second "booster" relay connected in series with the relay of the positioner to increase the speed of operation of the valve. His paper should be consulted for further details of this work.

5. Outstanding Problems

Having completed the review of the current state of the theory of pneumatic systems, it is interesting finally to look at one or two problems which have not yet received a satisfactory treatment.

It will be realised, of course, that even the representation of a controller or transmitter with time constants in the feedback loop and saturating amplifiers involves many gross approximations and simplifications. One obvious omission from the model is the inertia of the mechanical components included in the feedback loop of a force balance device. This is normally very small for controllers, though its importance increases as the pneumatic time constants are reduced (several commercial controllers will pass into spontaneous "pumping" oscillation if the relay output is blanked off), but differential pressure cells are normally of much heavier construction with a corresponding increase in the importance of inertial effects. If the operation of a force-balance differential pressure transmitter is analysed, it will be found that the inertia of the beams in the feedback system is effectively augmented by the inertia of the liquid in the cell and connecting lines, while the damping due to the hydraulic damper usually fitted is augmented by the viscous damping of the fluid in its movement through the connecting lines. It is therefore to be expected that the effect of long connecting lines on the stability of a differential pressure cell will depend on the relative values of the density and viscosity of the working fluid. To the author's knowledge no systematic investigation of these effects, either experimental or theoretical, has so far been published. It should be noted, incidentally, that the inertia of the mechanical system and the working fluid would not be included in the feedback loop in a motion balance arrangement, and should have no effect on the stability.

In the discussion of saturation effects in the previous section it was assumed that the controller and load were closely coupled, so that the feedback pressure could only rise as quickly as the load pressure. When a long length of pneumatic transmission line is interposed between the output and the load this coupling is reduced and rough experiments have shown that the transient behaviour of the system passes over towards that shown in Fig. 6 (a). The theoretical investigation of the transition from switching to linear behaviour would present an interesting but difficult problem in non-linear mechanics and has not, so far, been attempted.

Finally, a number of interesting phenomena occur when the parameters of a system are varied so that it passes into "pumping" oscillations and back again to stability. Taking the example of a valve positioner with booster mentioned in the last section, it is well known that the severe oscillations can be tuned out by gradually opening a needle valve connected in a by-pass between the input and output of the booster relay. A very marked "hard excitation" effect occurs at the transition from stability to instability, the amount of by-pass opening needed to damp out an existing oscillation being much greater than the amount needed to re-start the oscillation from a stable state, provided all adjustments are made slowly. The author[11] has discussed the established oscillations in this system with no by-pass round the booster, but a treatment of the transition from stability to instability has not, so far, been given. It involves non-linear differential equations of the third order which cannot be treated geometrically by the usual phase-plane methods.

References

1. G. H. Farrington. Theoretical Foundations of Process Control. *J. I.E.E.*, **94** (1), Part IIA, 1947, p. 23.
2. D. B. Kirk. Nozzle Flow Characteristics in Pneumatic Force-balance Circuits. *Trans. A.S.M.E.*, **15**, 1948, p.111.
3. C. I. Rutherford. The Practical Application of Frequency Response Analysis to Automatic Process Control. *Proc. Inst. Mech. Eng.*, **162**, 1950, p. 334.
4. A. R. Aikman and C. I. Rutherford. The Characteristics of Air Operated Controllers. Automatic and Manual Control, 1952, Butterworths.
5. J. M. L. Janssen. Analysis of Pneumatic Controllers. Automatic and Manual Control, 1952, Butterworths.
6. L. A. Gould and P. E. Smith, Jun. Dynamic Behaviour of Pneumatic Devices. *Instruments*, **26** (6, 7), 1953.
7. H. Williamson. Pneumatic Controllers, with Particular Reference to the Interaction Factor. *Trans. Soc. Instrum. Tech.*, **6** (4), 1954, p. 162.
8. A. J. Young. An Introduction to Process Control System Design. 1955, Longmans.
9. C. R. Webb. Non-linearities in a Pneumatic Controller. *Trans. Soc. Instrum. Tech.*, **7** (1), 1955, p. 9.
10. J. H. Westcott. Determination of the Parameters of a Controller by Simple Frequency Measurements. *Trans. Soc. Instrum. Tech.*, **9** (3), 1957, p. 79.
11. R. Jackson. A Non-linear Theory of the Dynamical Behaviour of Pneumatic Devices. *Trans. Soc. Instrum. Tech.*, **10** (4), 1958, p. 161.
12. British Standard, 1523 (1949).

General

THERE is no simple criterion for the resistance of a material to abrasion and in the absence of a theoretical guide the permanent indentation hardness, e.g., the d.p.h. number, of the material is frequently useful as a practical index, the abrasion resistance generally increasing with the d.p.h. One can therefore expect the d.p.h. numbers for insulating coatings and resistance alloys to be some guide to their withstanding being cut by an abrasive powder.

Repeatable d.p.h. values obtained on insulating resin coatings and on electrical resistance wires are:

(a) polyvinylacetal wire enamel, 0·004 in. thick.
Associated Automation—G.K.N. microhardness tester, 10 gram load.
21-25 d.p.h.

(b) modified phenolic wire enamel, 0·015 in. thick.
Vickers hardness tester, 1 kilogram load, and A.A.-G.K.N. microhardness tester, 10 gram load.
10-12 d.p.h.

(c) epoxy potting resin, 0·5 in. thick.
Vickers hardness tester, 1 kilogram load.
22 d.p.h.

(d) standard oleo-resinous wire enamel, 0·0002 in. thick.
A.A.-G.K.N. microhardness tester, 10 gram load.
Order of 14-20 d.p.h.

Measurement (d) was not definite because of the flow of the enamel under the diamond penetrator. It appears however that insulating resin coatings on wires are probably of the order of 15 to 25 d.p.h.

D.P.H. values, together with melting points of various common electrical resistance alloys, electrical contact alloys and metals and alloys used for prccision instrument components are given for the degree of cold work normally applicable in Tables 1, 2, 3 and 4. The degree of anneal of very fine resistance wires is frequently not full and significant cold work may be done on them during winding; thus microhardness measurements with the Associated Automation—G.K.N. microhardness tester on 0·0016 in. diameter 80/20 nickel-chromium wire wound manually on a former of $\frac{3}{8}$ in. diameter and buffed with a chalk-filled p.v.c. wheel gave repeatable values of 350-374 d.p.h. with both a 10 gram and a 30 gram load, which compares with the figure of 196 d.p.h. in Table 1.

The commonest classification of hardness of abrasives is on the Mohs mineralogical scale. This scale, stated originally in 1821, is an order of rank of scratch hardness, the liquid state being regarded as hardness rank 0 and diamond as hardness rank 10. Minerals are allocated ranks between these numbers according to whether a sharp point of one does or does not scratch a flat face of another. Mohs closely specified particular forms of certain minerals to define the integral ranks from 1 to 10 and recommended estimation of ranks between any two integers by comparing responses to scratching with a file (ref. 1, pp. 84-93, ref. 2, pp. 131-132, ref. 3, pp. 859-860). An inadequacy of the original scale is the closeness of ranks of the harder materials, viz. quartz 7, topaz 8, corundum 9 and diamond 10; beginning with the rank 7 a new scale of minerals has therefore been stated culminating with diamond having rank 15. The old Mohs scale is still the most used. Below a Mohs hardness of 7 the scale is of much help to the mineralogist as a means of classification and it is from this range that abrasives for buffing and polishing potentiometers and instrument parts can be usefully selected. Table 5 gives the Mohs hardnesses together with melting or decomposition points of some compounds and minerals which are commonly used as abrasives together with others of interest arranged in

Part 2

Resilient Buffing Whe Pr

TABLE 1
Electrical Resistance Alloys (Base)

Alloy	D.P.H. (fully annealed)	Mohs Hardness (estimated from Fig. 1)	Melting Point (Solidus) °C
Copper (pure)	35	2·9	1083
Mancoloy 10 (96% Cu)	75	4·2	1040
Telcuman Manganin (85% Cu)	80	4·4	1080-1100
Kumanal (88% Cu)	80-95	4·6	950
Minalpha	100	4·8	950-980
Copper-nickel (56/44)	156	5·9	1220-1270
Nickel-chromium-iron (65/15/20)	186	6·3	1350-1400
Nickel-chromium (80/20)	196	6·5	1400-1420
Karma	200-230	6·6	1400

By K. F. SHRUBB, B.Sc.(Eng.), D.F.H., A.M.I.E.E., A.M.I.Mech.E.
(Elliott Brothers (London) Ltd.)

Wher Precision Potentiometers and Instruments

ascending order of hardness.

Before considering the matter further some idea is required of the possible correlation between permanent indentation hardness such as d.p.h. and Mohs hardness so as to be able to determine the approximate Mohs hardness of a material from its indentation hardness. Auerbach (ref. 3, p. 866) gives a correlation for the ten minerals of the old Mohs scale between Mohs hardness and Auerbach absolute hardness which is an estimate by mutual indentation. O'Neill (ref. 4, pp. 138-140) gives correlations between Mohs hardness, indentation, scratch and pendulum hardness tester estimations for various materials. R. A. Hadfield was studying the correlation with Brinell hardness number for steels in this country about 1917 (ref. 5). Williams (ref. 1, pp. 96 and 134) shows the correlations between the ten Mohs mineral numbers and various scratch hardness testers.

A plot of estimates from reference books of d.p.h. number against Mohs hardness for twenty-four metals and alloys and four compounds is shown in Fig. 1. The form of this is the same as shown in the references quoted. From this figure it can be concluded that there is a very approximate correlation which is useful for the present purpose below a Mohs hardness of about 7

TABLE 2
Electrical Resistance Alloys (Noble)

Alloy	D.P.H. (fully annealed)	Mohs Hardness (estimated from Fig. 1)	Melting Point (Solidus) °C
Silver (pure)	26	2·5	961
40% Ag-Pd	95	4·8	1290
10% Rh-Pt	100	4·9	1850
10% Ir-Pt	120	5·3	1780
20% Ir-Pt	200	6·5	1815
10% Ru-Pt	200	6·5	1780
5% Ru-15% Rh-Pt	140	5·7	1830
20% Cu-Pt	145	5·8	approx. 1600
8% W-Pt	300	7·1	1890
5% Mo-Pt	100	4·9	approx. 1800
5% Mo-40% Pd-Au	140	5·7	approx. 1450

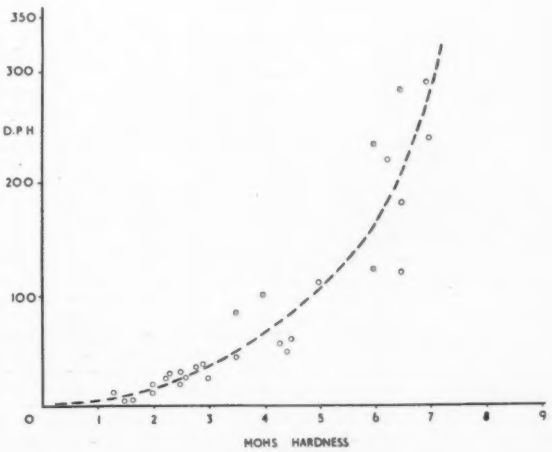


Fig. 1. *Correlation of d.p.h. and Mohs hardness*

corresponding to a d.p.h. number of 280, the correlation being more defined the lower the Mohs hardness.

On this basis reading from the figure the Mohs hardness of insulating resin coatings is about 1·9-2·4. This is substantiated by such coatings not being scratched by the finger nail, the Mohs hardness of which is usually taken as 2·5. Fully annealed 80/20 nickel-chromium wire of about 196 d.p.h. is seen from the figure to have a Mohs hardness of about 6·5.

Study of rubbing solids at Cambridge (refs. 6, 7, 8) has shown the importance of relative melting points of abrasive and work in abrasive polishing processes, polish being produced on the lower melting point component even though it be harder. Bowden and Hughes showed that litharge PbO (Mohs 2, melting point 888°C) will polish speculum metal (Mohs 3-4, 50 d.p.h., melting point 745°C) but will not polish nickel (Mohs 5, 164 d.p.h., melting point 1,452°C). These results are

TABLE 3
Electrical Contact Alloys

Alloy	Hardness				Melting Point (Solidus) °C
	Fully annealed		60% reduction of area		
	D.P.H.	Mohs (from Fig. 1)	D.P.H.	Mohs (from Fig. 1)	
Ag	26	2·5	—	—	961
Ag electrodeposited	110, Mohs 5·1				961
7½% Cu-Pd	56	3·7	140	5·7	778
40% Cu-Pd	145	5·8	260	6·9	1200
10% Cu-Ag	62	3·8	140	5·7	778
20% Cu-Ag	85	4·5	150	5·9	778
50% Cu-Ag	95	4·8	160	6·0	778
Cu-Ag-Au (625 Alloy)	165	6·1	230	6·7	861
10% Au-Ag	29	2·6	80	4·4	965
10% Ir-Pt	120	5·3	180	6·3	1780
20% Ir-Pt	200	6·5	270	7·0	1815
25% Ir-Pt	240	6·8	310	7·1	1845
30% Ir-Pt	285	7·0	—	—	1885
Ir-Pt-Ru (Irru)	310	7·1	—	—	1890
J.M.282	110	5·1	300	7·1	1000
5% Pd-Ag	33	2·8	95	4·8	965
10% Pd-Ag	40	3·1	100	4·9	1000
20% Pd-Ag	55	3·6	130	5·5	1070
"C" Pt	65	4·0	115	5·2	1769
Pt electrodeposited	300-400, Mohs 7·3				1773
Pt-Ag-Au (PGS Alloy)	60	3·8	140	5·7	1100
Hard Au electrodeposited	115-120, Mohs 5·2				1063
Rh electrodeposited	800, Mohs 8+				1960
4% Ru-Pt	130	5·5	200	6·5	1775
10% Ru-Pt	200	6·5	300	7·1	1780
30% Ag-Au	32	2·7	100	4·9	1025
40% Ag-Pd	95	4·8	190	6·4	1290
W	290, Mohs 7·0				3400

substantiated independently by experience with zinc monoxide (Mohs 4-4·5, melting point 1,975°C) which readily produces polish on quartz (Mohs 7, melting point 1,713°C) and with manganese dioxide (Mohs 6-6·5, decomposition point 535°C) which, while being in fact an excellent polishing agent for glasses and alloys, is extremely slow. Polishing powders have been shown to give similar results to solid block polishers.

Grinding and polishing processes are different in mechanism, abrasives for grinding being always harder than the work while those for polishing are generally softer. The particle size of the abrasive and the speed of cutting are important in both processes. In buffing precision potentiometers and instrument parts in which final dimensional accuracy is important the need is to remove a coating by grinding and to polish the remaining alloy; because of the small amounts of material frequently being removed the distinction between what is grinding and what is polishing is ill-defined. The relative hardnesses of the abrasive and coating are important in removing the coating while in polishing the remaining alloy the relative melting points of the abrasive and the alloy may be predominant.

Insulating resin coatings including oleo-resinous, polyvinylacetal, polyester, silicone and epoxy resin-based enamels all begin to go brittle or soften in the range 150-200°C, their behaviour depending on the combined effect of temperature, time and pressure. Microscopic examination shows that a resin coating can become progressively thinner as buffing is continued, suggesting a simple abrasion process. However, apparently furled edges to the resin coating at the edges of the buffing region have sometimes been observed, suggesting that considerable softening of the resin coating may occur during buffing.

Further, in the action of the p.v.c.-bonded resilient buffing wheel the effect is added of the p.v.c. softening progressively at temperatures from about 140°C upwards, the degree of its flow also depending on the pressure. For efficient buffing the p.v.c.-bonded wheel should be used in such a way that large scale softening does not occur but it is possible that highly localised softening does occur during buffing, so modifying the way in which the abrasive is presented to the work.

Experience so far indicates that the effects of the p.v.c.-bond softening can be neglected as a primary factor. This suggests that the choice of abrasive for precision buffing should be made on the basis only of relative hardnesses and melting points, always assuming that the abrasive has very small particle size.

Nevertheless, recommended abrasives from practical experience should also be considered (bearing in mind that final dimensional accuracy is frequently not of importance for the purpose for which they may have been recommended) since they disclose many anomalies in the light of a simple theory. Twyman (ref. 2) discusses and gives much useful information about the nature of fine grinding and polishing. Glazebrook (ref. 9) discusses the practical choice of abrasives. The application of diamond powder, aluminium trioxide and red rouge is well-known. Chromium oxide is much used for stainless steel and gold in dentistry while rouge and zinc monoxide are both used for gold. Zinc monoxide, rouge and chromium oxide will all readily polish quartz and glasses. Stannic oxide (putty powder) is used for polishing glass but is also used in some dentifrices in small proportions to give a high gloss to the teeth. Charcoal can be used for final polishing of glass while colloidal graphite (for example, Indian ink) and manganese dioxide have been used for the same purpose. Silver plate powders are usually no harder than chalk. Vulcanite and acrylic resins can be polished with chalk, calcium sulphate, tripoli powder or rouge. Dentifrices contain abrasives of not more than Mohs hardness 3·5 (except for the occasional inclusion of small amounts of stannic and strontium oxides), chalk being the most used, together with calcium phosphate, magnesium carbonate and magnesium oxide, all of which are said to scratch more than chalk although they do not scratch tooth enamel; kaolin and dibasic calcium phosphate $CaHPO_4$ are also used, the latter being said to have the least scratching action of any dentifrice abrasive.

Choice of Abrasive

Tables 1, 2 and 5 can now be examined to study what the present theory indicates as a suitable abrasive to remove an insulating coating from an electrical resistance alloy without removing any of the alloy. The abrasive selected should have a higher Mohs hardness and melting point than the coating but a lower hardness and melting point than the alloy, bearing in mind that the abrasive may decompose during buffing into a compound which may in particular have a higher melting point.

For enamelled nickel-chromium and enamelled copper-nickel potentiometers the tables suggest $PbCO_3$, NiS, CuO and ZnS with $PbSO_4$ and Na_2SO_4 as slower but safer choices. For enamelled silver-palladium wires they suggest CuCl, $PbSO_4$ and Na_2SO_4. For enamelled

TABLE 4
Alloys for Instrument Components

Alloy	Hardness		Melting Point (Solidus) °C
	D.P.H.	Mohs (from Fig. 1)	
Gold	20 (annealed)	2·2	1063
Gold	65-70 (pure electro-deposited)	4·0	1063
Hard gold plating	115-120	5·2	1063
Iridium	220 annealed	6·6	2454
Nickel	120	5·3	1452
18% Nickel silver	240 (spring temper)	6·8	1000
6% Phosphor bronze	210-225 (spring temper)	5·5	930
Beryllium copper (Mallory 73)	350-420 precipitation hardened	7·3	900
Duralumin	130	5·5	660

TABLE 5

Compounds and Minerals in Mohs Hardness Order

Compound	Mohs Hardness	Melting or Decomposition Point °C
Carbon (amorphous)	0·5-1	3600
AgI	1	540
Talc	1	
AgCl	1-1·5	455
Na_2CO_3	1-1·5	852
HgCl	1-2	
Alabaster	1·7	
S	1·5-2·5	107
KCl	2	790
NaCl	2	801
PbO	2	888
$CaSO_4$	2	1360
CuCl	2-2·5	418
Ag_2S	2-2·5	
Kaolin	2-2·5	
AgBr	2·3	434
Pb_3O_4	2·5	500-530 dec.
Na_2SO_4	2·3	883
$PbSO_4$	2·75	937
PbS	2·75	
Cu_2S	2·5-3	
Mica	2·8	
$CaCO_3$	3	898 dec.
$BaSO_4$	2·5-3·5	1580
$MgSO_4$	3-3·5	150 dec.
NiS	3-3·5	797
MgO	3-3·5	2800
$PbCO_3$	3-3·5	
CuO	3·5	1148
$Ca_3(PO_4)_2$	3·5	1550
CaO	3·5	2572
$CaHPO_4$	3·5	
Rottenstone	3·5?	
Vienna Lime CaO.MgO	3·5?	
$MgCO_3$	3·5-4	350 dec.
ZnS	3·5-4	1050
Cu_2O	3·5-4	1210
$CuCO_3$	3·5-4	
$FeCO_3$	3·5-4·5	
ZnO	4-4·5	1975
$ZnCO_3$	4·5-5	300 dec.
NiO	5·5	1990
PbO_2	5·5	
Glass	4·5-6·5	600-800
Fe_3O_4	6	1538 dec.
Fe_2O_3 (red rouge)	5·5-6·5	1560 dec.
MnO_2	6-6·5	535 dec.
SnO_2	6-7	1130
Tripoli	6-7	1713
Pumice	6-7	
CeO_2	6-7	
TiO_2 (rutile)	6·7	1825
SiO_2	7	1713
Cr_2O_3	7-7·5	1990
Emery	7-9	
WC	8·5	
Al_2O_3	9	2050
SiC	9·5	
B_4C	9·5+	
Diamond	10	3600

Mancoloy potentiometers the margins are finer but Na_2SO_4, Pb_3O_4 and CuCl with PbO and NaCl as slower but safer choices are suggested.

For oxy-insulated (nickel oxide) nickel-chromium potentiometers a choice cannot be made on the basis stated since the melting point of the coating is well above that of the alloy. This combination is difficult with any abrasive technique. The resilient wheel technique has the advantage of removing the coating over the wire contour at an even rate since the bond

swathes the contour if it is soft enough. Using an abrasive only slightly harder than the coating such as Fe_3O_4 or PbO_2 the removal of the alloy will be minimised. ZnO can be used but will be slower cutting. Tripoli powder removes the oxide satisfactorily but abrades the alloy fairly rapidly. Chalk is quite ineffective.

It has been said that chalk is satisfactory for enamelled nickel-chromium wire and that it is useful as a general purpose abrasive. In spite of the high melting point of calcium oxide, into which chalk may decompose, copper and Mancoloy windings have been successfully buffed with it provided care is taken. Nevertheless some of the alloy is certainly removed and the wheel should not be too hard or run at too high a speed. Kaolin is very slow on enamelled coatings while rouge rapidly cuts nickel-chromium, both effects substantiating deductions from the tables. The subject of choice of abrasive calls for further experimental work.

Before embarking on work where final dimensional accuracy is of major importance the proposed wheel specification must be tried out, but experience shows that except with such a case as a nickel oxide coating on nickel-chromium a satisfactory choice having fairly large tolerances in use can be made. As a start in a doubtful instance chalk should be chosen as the abrasive and the results observed. Ultra-precision buffing demands that the buffing process should be mechanised, using automatic control of buffing pressure and duration over all parts of the contact track.

Pumice is used as a filler having abrasive properties in white rubber dental polishing wheels and in pencil and ink erasers. Its rate of cutting all resistance wire materials is rapid however and even when used with an elastic bond the contour-following property of a buffing wheel incorporating it is poor. A typical tracing eraser for Indian ink contains B.S.410, 120-mesh pumice and a typewriter eraser contains a mixture of 60-mesh and 120-mesh pumice. The nominal aperture size of 60-mesh is 0·010 in. very nearly and of 120-mesh 0·005 in. very nearly. If such erasers are used to buff potentiometers the risk of abrading much of the resistance material and of making deep cuts in fine gauge wire is therefore high. Further, with rubber as the bond there is always the risk of depositing adherent smeared rubber on the winding and in the valleys between turns.

Applications of Resilient Buffing Wheels in Instrument Manufacture

By substituting successively harder fillers from talc up to aluminium trioxide for the chalk included in the p.v.c. material formulation given in Part I, a range of resilient buffing wheels of great utility in the instrument workshop can be made for buffing miniature contoured and other parts, especially where final dimensional accuracy is important. Talc and kaolin wheels will polish plastics and enamels, magnesium carbonate or chalk wheels can be used to polish gold and silver contacts, gold slip rings, duralumin gear teeth of the finest pitch, brass separators in miniature ball-races and the tips of recorder pens and styli, rouge wheels can be used to burnish ball-ended cone and parallel pivots, fine screw threads, steel splines and gear teeth, and aluminium trioxide wheels will deburr and burnish hardened steel threads and teeth of any pitch. Resilient buffing wheels can remove dirt from fine depressions when only ultrasonic methods might otherwise be adequate and they can be chosen to do their job swiftly and with a large safety margin. Chalk-filled wheels are highly successful in cleaning dirt from engraving, chasing and engine-turning on metal jewellery.

To buff a contact track on the inside surface of a rectangular section toroidal potentiometer a suitable diameter thick cylinder can be cast of p.v.c. material filled with a fairly hard abrasive such as rouge or aluminium trioxide. This is mounted on a screwed rod through the centre of the toroid and first compressed axially with suitable nuts and washers so that a pressure for buffing is exerted against the inside toroid surface. The rod is then rapidly oscillated axially to abrade the insulating coating on the wire. The elastic buffing material in intimate contact with the wire produces highly reliable contour-following buffing as with the wheel technique. Hard abrasive is generally necessary because of the low mean speed of the buff over the work.

Rods of p.v.c. material filled with chalk or other abrasive cast in the form of a lapping stick round a rigid former are generally useful for touching up work. Chalk-filled p.v.c. sticks have been used regularly for removing tarnish from precision potentiometer contact tracks and from contact surfaces.

Synchros and Servo-motor Rotors

Most of the foregoing is equally applicable to assemblies of stacked laminations, particularly in connection with the modern practice of bonding fine component rotors by using epoxy resins as insulator and adhesive. The technique described has application in the preparation of the rotors of synchros and servo-motors and in the reduction of "flash" between laminations. Elimination of inter-lamination contact by use of a technique which cleanly removes the excess bond material without damage to laminations is of obvious benefit in reducing unwanted residuals and harmonics.

It will moreover be obvious that the whole usefulness of the studies outlined will include applications not referred to here.

Summary

Methods of buffing insulating coatings from electrical resistance wires to make contact tracks on potentiometers have been described, which use a selected abrasive as a filler in a friable elastic bonding medium, either rubber or p.v.c. being recommended according to the nature of the work. They are markedly superior to most conventional methods. The contour of the as-drawn wire is closely preserved and a high burnish left on the wire with all gauges of resistance wire down to the finest commercially available (0·0005 in. diameter).

Present knowledge about fine grinding and polishing techniques draws attention to the importance of melting point as well as hardness and suggestions for suitable abrasives for buffing potentiometers can be made in the light of these.

A range of resilient buffing wheels and resilient lapping sticks filled with selected abrasives from very soft to very hard is a valuable aid in the instrument workshop.

The user can readily make p.v.c.-bonded resilient buffing material to his own specification without special equipment.

Acknowledgments

The author wishes to acknowledge assistance freely given by William Canning and Co. Ltd., British Geon Ltd., Johnson, Matthey and Co. Ltd., The London Electric Wire Company and Smiths Ltd., and Hilger and Watts Ltd., and to thank Mr. W. H. Alexander, Chief Engineer, Aviation Division, Elliott Brothers (London) Ltd., for encouragement and permission to publish this paper.

References

(1) Hardness and Hardness Measurements. S. R. WILLIAMS (American Society for Metals, 1942).
(2) Prism and Lens Making. F. TWYMAN (Hilger and Watts, 1952).
(3) F. AUERBACH. Handbuch der Physik (ed. A. WINKELMANN), Vol. 1 (Barth, Leipzig, 1908).
(4) The Hardness of Metals and its Measurement. H. O'NEILL (Chapman and Hall, 1934).
(5) A Dictionary of Applied Physics (ed. R. GLAZEBROOK), Vol. 5, p. 519 (Macmillan, 1923). (Hadfield reference quoted therein is incorrect.)
(6) F. P. BOWDEN and K. E. W. RIDLER, 1936, *Proc. Roy. Soc.*, A, **154**, p. 640.
(7) F. P. BOWDEN and T. P. HUGHES, 1937, *Proc. Roy. Soc.*, A, **160**, p. 575.
(8) Theory of Polishing. D. TABOR, *Bulletin No.* 4, Feb., 1949, Design and Research Centre for the Gold, Silver and Jewellery Industries, London.
(9) A Dictionary of Applied Physics (ed. R. GLAZEBROOK), Vol. 4, p. 339 (Macmillan, 1923).

Automatic Machine Tool Control Systems

FERRANTI LTD. have recently developed two new machine tool control systems, one is a transistor/hydraulic continuous system, and the other is a numerical position control system. Both equipments should be acceptable to small as well as large engineering companies.

Transistor/hydraulic Continuous Control System

With the Mark IV transistor control system three hours of machining can be accomplished with one magnetic tape. The complete system operates from normal mains electricity without the use of frequency converters.

The Preparation of Drawings

Drawings for controlled machine tools differ from those generally used for conventional machining. They can be compared with data sheets for jig boring, in that all dimensions are given by a system of Cartesian co-ordinates from a common datum.

Planning the Component

As with manual methods of manufacture decisions have to be taken which will determine the best possible means of producing the component. The holding fixture, which for controlled machining should be very simple, must be specified; and standard clamping plates with location pins usually cover most requirements. The diameter and type of cutter together with the feedrate to be used must be determined and the method of machining decided. These factors are very important and should be given careful consideration.

Programming

Programme planning is a very simple operation, the programmer being concerned only with the writing down of the machining sequences in a code form. The Ferranti system has been designed to operate in conjunction with a computer and as a result no special mathematical knowledge is required of the programmer. An average machinist can be trained to do this work in a few hours.

The sequence of operations has already been established at the planning stage. The programmer, working from the co-ordinate drawing, determines the path of the cutter by writing down the change points as they occur on the periphery of the part to be cut. A change point can be defined as that point on the component where a change of direction is required. For example, two points are necessary to define a straight line, i.e., the beginning and end of that line, irrespective of its length. Three change points are used when defining a circular arc, the centre of the circle and the beginning and end of the arc. When a straight line, circle or second degree curve cannot be fitted to suit the shape required, interpolation can be used so that a smooth curve is produced through a number of specified points given along the curve.

Straight lines, circles, conic sections and interpolation can be called for by the programmer at will simply by writing in a code word such as CIR (circle), ELL (ellipse), INT (interpolation). Where no code word is written the co-ordinates are treated as defining a straight line.

It is important to note that the programmer is concerned solely with specifying the dimensions of the part, the feedrate, and the diameter of the cutter being used. The computer accepts this information and calculates the centre line of the cutter path together with acceleration and deceleration at points of change.

Typing the Programme Sheet

The programme as written by the programmer has to be transcribed into a form which can be accepted by a computer. A standard teleprinter is used for this operation and normal copy-typing only is involved.

The typist copies the written programme sheet on the teleprinter and, as a result, a black-typed copy is produced together with a five-hole punched paper tape, this being the input of information to the computer. The black-typed copy can be compared with the original written sheet as a typing check, or alternatively, the paper tape can be put through the tape reading mechanism associated with the teleprinter to produce a red-typed copy. If these three are checked against each other all risk of error is eliminated.

Computer Centre

The operations already described, up to and including the paper tape preparation, is the responsibility of individual manufacturing organisations.

The prepared paper tape is sent to one of the Ferranti Computer Centres which are situated in Edinburgh and London. As the demand for computation grows, further centres will be established in other parts of Great Britain and overseas.

The paper tape is received at the Computer Centre and, after documentation, is passed to the computer operators for computation. The computer records the programme very rapidly—eight times faster than it is played back on the machine tool, hence one computer is capable of supplying tapes to a large number of equipments. If an error in programming is detected at the computer, the paper tape is referred back to a Ferranti programming engineer who finds and rectifies the mistake. When this is not possible every effort is made to clarify the situation by the most expeditious method.

As an additional check against programming errors a drawing machine is coupled directly to the computer. This drawing machine, which operates simultaneously with the recording unit, produces a drawing of the part to be machined, either full size or to a pre-determined scale.

The recorded magnetic tape, together with the check drawing and original paper tape, are returned to the customer. Computation requests which are received at the Computer Centre in the morning of any given day are despatched back to the originator by the evening post, hence a 24-hour service is obtained. An emergency service can be used whereby this period can be further reduced, using air freight or passenger train service.

General Purpose Computers

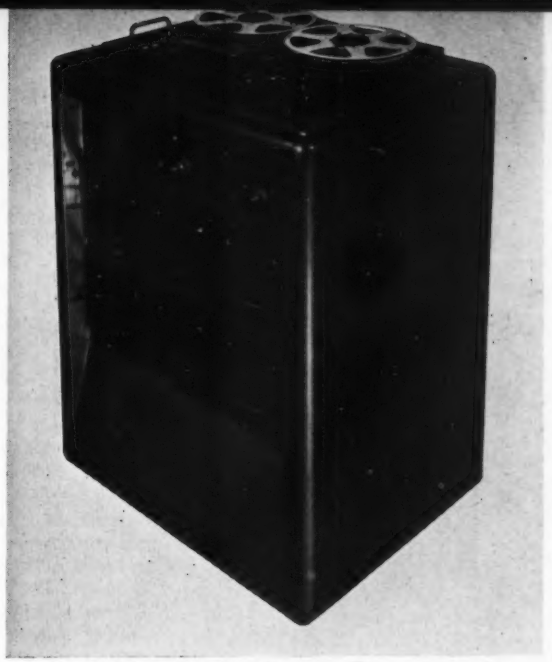
Many of the larger engineering companies have installed general purpose computers to solve technical problems of design and to cope with data processing associated with stores control and wages. In many cases, time is available on these machines which could be used to produce magnetic tapes for machine tool control.

Ferranti Ltd. manufacture a range of curve generators which can be linked directly to any medium-sized general purpose computer to produce control information on magnetic tape; this tape is then used as the direct input of information to the control console.

A fast curve generator can be supplied, which is not directly linked to the general purpose computer, but accepts the existing computer output in the form of magnetic tape, paper tape or punched cards.

Controlled Machining

The magnetic tape which is received back from the Computer Centre contains the full information necessary to machine the component. These tapes have been perfected to withstand normal workshop conditions so that no special precautions are necessary other than the usual care taken with toolroom equipment.



The control console for the new Ferranti continuous machine tool control system. The transistor circuitry for each axis of the machine tool is contained in easily replaceable trays simplifying maintenance in the field

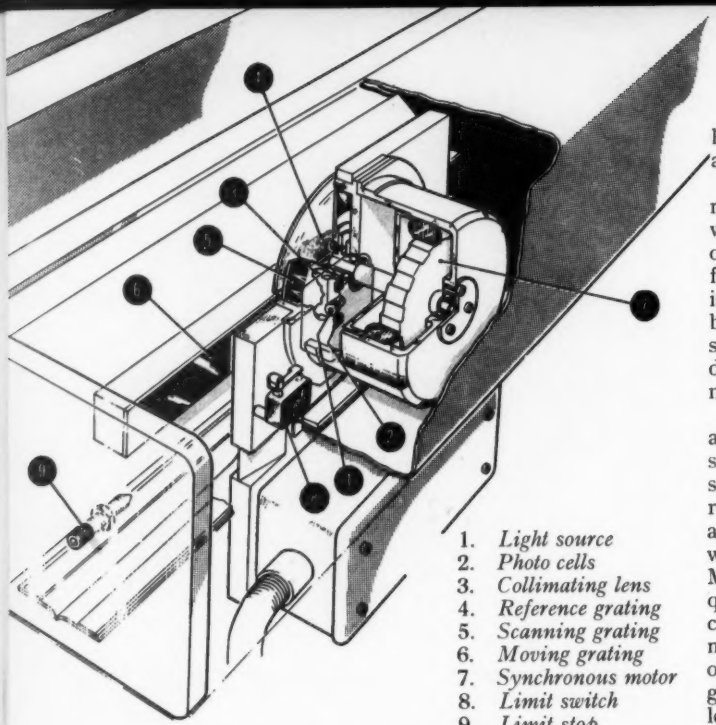
The component blank is clamped to the simple holding fixture and the correct cutter inserted into the quill of the machine. After selecting the spindle speed to suit the cutter diameter and setting the tool over the datum point, machining is ready to commence. During machining no supervision is necessary other than for chip removal and coolant control. If for any reason the equipment fails or if an error is detected by the checking device operating from the measuring system, the machine tool stops instantly.

The magnetic tapes can be used indefinitely to produce the same component, or alternatively, if only a limited number of components is required, the tape can be erased and used for a subsequent programme, in which case the paper tape is retained as the record.

Control Cabinet

This unit contains the magnetic tape deck, electronic equipment and power supplies to control the three axes of the machine tool. The electronic equipment has been entirely designed around semiconductors and no thermionic devices are used. The power consumption and thermal dissipation is low and as a result a very high reliability can be assured.

The circuitry is assembled in the form of plug-in cards housed in four removable drawers. Each axis of the machine is controlled from a single drawer assembly and in addition one drawer is used as a reference for all axes. The 'X' (longitudinal control), 'Y' (transverse control) and 'Z' (vertical control) drawers are identical and interchangeable so that only two drawers have to be carried as spares, one covering the three axes, and one for reference.



1. *Light source*
2. *Photo cells*
3. *Collimating lens*
4. *Reference grating*
5. *Scanning grating*
6. *Moving grating*
7. *Synchronous motor*
8. *Limit switch*
9. *Limit stop*

Typical layout of driving and measuring equipment for the new Ferranti continuous machine tool control system

The Hydraulic Servomotors and Gearboxes

The drives to the three slides of the machine tool are provided by 3 b.h.p. hydraulic motors driving through a backlash-loaded gearbox to the transmission of the machine tool.

The gearbox is designed for minimum inertia, maximum stiffness and zero backlash in the output train. The gears are designed, case-hardened and profile ground in accordance with British Standard Specification 436 to give 26,000 hours life when run at 4 b.h.p continuous loading at 60 r.p.m. output, thus ensuring long and trouble-free life for the gearbox.

For small machine tools hydraulic rams are used as a transmission method and are controlled by electro-hydraulic valves. These rams operating in conjunction with the Ferranti displacement measuring system can, on small machines, give a performance equivalent to more complex transmissions.

The hydraulic power supply to these servomotors is specified with a suitable supply pressure and maximum delivery flow. A constant volume pump is used for this purpose providing pressures up to 1,500 p.s.i.

Measuring System

Associated with each slide of the machine tool is a measuring system which monitors the actual movement demanded from the control cabinet. The accuracy of the machine tool transmission is unimportant, as displacement is measured and transmission errors corrected, from the measuring system.

The essential element of the Ferranti measuring system is a length of reflecting optical grating carrying a line structure with a precisely known number of lines to the inch. The direction of the lines is at right angles to the length of the grating.

This line structure is continuously scanned by a revolving transparent disc carrying a spiral pattern whose line structure along a radius is identical to that of the reflecting grating. The shadow band (moiré fringe) resulting from the interaction of the two gratings is detected by a photocell. The illumination along this band varies with time to give an approximately sinusoidal waveform. The frequency of this waveform depends on the speed of rotation of the spiral and the number of spiral starts.

Consider a small cross section of the spiral pattern as viewed by the photocell. This appears similar to a section of linear grating moving from left to right at a speed of 104 shadow bands per second. If there is relative movement between the rotating spiral assembly and the linear grating in a left to right direction this will produce an output frequency lower than 104. Movement in the opposite sense will produce a frequency higher than 104. The frequency relative to 104 cycles gives a measure of the sense and speed of movement and the phase gives an accurate indication of instantaneous position. Three different pitches of grating are available, 100, 40 and 10 lines per inch length. These are used with 50 digits per pitch giving digit sizes of 0·0002 in., 0·0005 in. and 0·002 in. respectively.

As a refinement to minimise possible errors due to eccentricity in the rotating spiral, an additional channel has been introduced whereby the spiral is monitored at a point adjacent to the main viewing area. In this case, however, the grating being scanned is fixed to the synchronous motor body. The frequency of the output waveform is constant at 104 c/s. Slight eccentricity of the spiral disc will produce phase variations of a few degrees and these will closely follow similar variations in the main signal channel. A correction signal is produced by feeding this signal, together with the 104 c/s carrier waveform from the tape, into a second phase comparator. The output of this subtracted from the main error signal eliminates any error due to spiral eccentricity from the system.

The measuring system is free from friction and wear and can be installed as a compact unit along the edge of or underneath the machine table. Since information is being obtained from a relatively large area of grating, lengths of grating can be placed end to end with small gaps if necessary. The gratings are made from stainless steel with alternate etched and reflecting lines. A complete measuring system is required for each controlled machine axis.

Overall Performance

The compactness of the control console (overall size 29 in. × 23 in. × 43 in. high), the low power consumption (400 watts) and the ease of servicing all reflect the advantages of using semiconductors. It has been possible to retain all the important operational features such as automatic checking, miscellaneous function controls and fail-safe performance in spite of the radical alteration of the circuit logic.

The price of the new system ranges from £700 to £1,200 depending on the size and complexity of the machine tool being controlled.

Numerical Position Control Equipment

This equipment has been designed for rapid point-to-point positioning of machine tools and allied equipment in Cartesian or polar co-ordinates. Measurement of position is by means of the diffraction grating measuring system fitted to the machine tool slides or tables. A new clutch servo-mechanism has been added to the current Ferranti range for general-purpose use with position control equipment, but for special-purpose use the equipment is compatible with any servo-mechanism in the range.

A new tape reader has been developed for the information input. Standard $\frac{5}{8}$ in. wide punched tape is used, but instead of the usual system of sequential reading of single characters, a whole block of information is read at a single position. This minimises the time taken to transfer the co-ordinates into the control system and obviates the need for additional information storage.

Control Console

The tape reader, manual coordinate-setting dials, numerical readout indicators if provided, all electronic equipment and power supplies are assembled in a floor-standing console. The size of this unit is 29 in. × 24 in. × 47 in. high. All controls and the tape reader are grouped for maximum accessibility at the top of the cabinet. The tape reader is provided with tape spooling equipment, the feed and take up spools accommodating 200 ft. of tape, sufficient for 600 three-dimensional position movements. Tape or dial input can be selected at will. Information space is allocated on the tape for controlling machine functions other than positioning so that a complete operating cycle such as drilling can be controlled.

The electronic equipment is built in the form of plug-in "cards", accessible behind a drop-down panel at the front of the console. Only four types of "card" are used and servicing is rendered extremely simple, an indicator lamp being actuated by the automatic error-check system to indicate the faulty channel. Only semiconductor circuits are used in the equipment, which is based on a newly developed high-speed transistor decimal counter provided with a continuous ternary checking circuit. This counter keeps a continuous record of the position of the machine slide from an arbitrary datum, which can be changed at any time and set to any point on the table. The input position is selected by tape or dials, a direction discriminator decides whether the co-ordinate in the counter is higher or lower than the demanded position and selects the direction of movement to bring the table position into coincidence with the setting.

The decimal counter is continuously checked by means of the ternary logic, so that in the event of a failure the equipment will stop automatically and will not function again until the defective circuit card has been replaced or repaired; thus there is no possibility of an incorrect setting due to failure. In addition a similar check is applied to the tape-reading equipment to obviate misreading the punched tape.

Measuring System

Gratings, either linear or circular, of pitch suitable for the accuracy required are fitted to each axis of the machine, rendering the accuracy independent of the leadscrews or other transmission elements.

Servomechanisms

The servopacks utilise a 50 c/s induction motor and two control clutches and gearing to give a two-speed drive. Fast approach speed up to 200 inches/minute can be provided, depending on the resolution required, and a final slow setting speed brings the table to rest at the correct setting two or three seconds after the changeover is made. At this point the slides are automatically clamped.

Variations in the Form of the Equipment

The equipment described covers the majority of applications for position control. Variations can be provided for special purposes, and two such variations are noteworthy.

For drilling heat-exchanger baffle plates and parts of a similar nature, where large numbers of holes (200 to 10,000) have to be drilled to a regular pattern, advantage is taken of this regularity to use an in-line multiple-spindle drilling head with an adjustable distance between spindles (which can be preset to a multiple of the distance between holes in the required pattern) and to simplify the punched tape programme. A series of dimensions, labelled ABCD, representing the distance between holes, the distance between rows of holes and other basic dimensions of the workpiece, is preset on dials on the control cabinet. The programme is now written in terms of movements which are multiples of these dimensions ABCD and selections of the particular drills required. A typical line of programme would be XA - 12 YC + 01Z123056 which means move X axis 12A units in direction of datum, move Y axis one C unit away from datum, then drill using drills 1235 and 6. The advantages of this system are that no tedious calculations are necessary to produce the programme, yet the positioning accuracy is the same as that of a co-ordinate programmed machine, and the time to produce a plate can be reduced by a factor of five by using the multiple head. While this is essentially a production machine, it is so easy to produce a programme and reset the machine, that a prototype plate can be produced for little more cost than a similar plate in full production. The use of standard 5-hole punched tape enables the tape to be prepared by a computer if this is an advantage, where, for example, a very large number of holes has to be drilled.

Many users find it necessary to divide a circle into a number of equal parts for equal-pitch flange holes, etc., and a system has been developed for doing this which, when used in conjunction with a circular table, can divide a circle into any number of equal parts, with a tolerance better than ±0·001 in. in position on the circumference of the table, irrespective of the table diameter. It is only necessary to preset a dial to the number of divisions required, for example 123, press the start button and the table will index through 1/123 of a revolution. This control may be used as a simple dividing engine or as part of an automatic drilling machine.

The price of the co-ordinate positioning control system with feedback checking and monitoring from electro-optical measuring scales is between £2,000 and £3,000.

Computers and the Electronic Office

By R. H. WILLIAMS, A.I.B., F.Inst.D.
Managing Director, Computer Consultants Limited

Part 5 Some Economic Aspects of the Commercial Use of Computing Systems

IN previous articles the use of electronic computing systems in commerce has been discussed, but little attention has been paid, as yet, to the economics of their use.

While it may be possible to carry out certain procedures on an electronic computing system, it may be very much cheaper to carry out the work in some more orthodox fashion and the improvement which a computing system might offer might in practice be greatly offset by the cost.

It is very difficult to measure, or even define, the results which can be expected or obtained from the use of a computing system.

In a few cases these can be actually measured and costed in relation to existing methods of carrying out the work, or measured against certain improved methods of carrying out the work on another type of equipment. In other instances, management can be provided with more up to date information and given better control of procedures, by the use of a computing system. As a result of this, management in turn is able to offer a better service or better goods to their own customers and can thus increase their turnover and probably their profits.

Costs of Computing Systems

In the early days of the use of computers, computer manufacturers frequently quoted for their machines at prices in the lower tens of thousands. This figure in itself was quite a substantial one and opinion was greatly disturbed when it was found in practice that it was not the beginning or the end of the cost of the installation.

The computer itself represents, costwise, about a third or a quarter of the cost of the whole system, the rest of the cost being made up in necessary peripheral equipment and various ancillary costs, such as programming, installation, preparatory work, system design, new stationery, readjusting of premises and other quite numerous lesser charges.

The following table gives the present general cost of complete commercial computer systems and refers to average complete systems at present quoted available in Britain:

Associated Electrical Industries	
1010	£170,000 approx.
Burroughs Adding Machine Ltd.	
220	£300,000—£600,000
205	£180,000 approx.
Elliott Brothers Limited	
802	£20,000 approx.
803	£35,000 approx.
402E	£28,000 approx.
402F	£38,000 approx.
English Electric Limited	
DEUCE Mk. I	£45,000
Mk. II	£50,000
Mk. IIA	£55,000
Ferranti Limited	
Pegasus I	£50,000
Pegasus II	£65,000—£160,000
Perseus	£200,000—£300,000
EMI Electronics Limited	
EMIDEC 110	£100,000—£250,000
2400	£200,000—£700,000
IBM United Kingdom Limited	
650	£70,000—£200,000
7070	£200,000—£500,000
705 II	£500,000—£1,000,000
305 RAMAC	£65,000

IBM United Kingdom Ltd. RAMAC computer

International Computers and Tabulators Ltd.	
1202	£50,000
1400	£150,000 upwards
Leo Computers Limited	
LEO II	£95,000 approx.
National Cash Register Co. Ltd.	
National-Elliott 405	£100,000—£180,000
National-Elliott 405M	£120,000—£200,000
Remington Rand Limited	
Univac Solid State Computer	£125,000
Standard Telephones & Cables Ltd.	
Stantec Zebra	£30,000

The figures given in this table are a general guide and of course will vary quite considerably, depending upon the additional equipment added to the system. In most cases the variation in price will tend to be upwards and not downwards.

These prices taken out of context could also tend to be misleading, insomuch that three very important other items have to be taken into account. The first of these is the cost of carriage and installation. In some cases this can be a considerable item, particularly where equipment is manufactured abroad. Some manufacturers include this cost in their selling price while others do not. Another item which has to be taken into account is the cost of the spares which have to be kept on hand by the user and which are sometimes required to be purchased from the manufacturer separately from the computer. This generally represents about ten per cent of the cost of the equipment, but in some cases the selling price includes initial spares for one year and in other cases, particularly where rental takes place, the rental itself covers the cost of spares as well as the cost of the maintenance of the computing system.

The third item of cost is maintenance. This is almost invariably included in the rental of the machine if the equipment is rented, but in cases where the equipment is bought it can be a major item of expense, particularly where several different manufacturers' equipment is used to make up a whole system.

In some cases where equipment is bought, the maintenance is undertaken by the manufacturer for a nominal sum or, alternatively, the user is not required to purchase the spares which he stocks locally but merely to pay for them as they are taken out of stock and used.

It will be seen from the above that there is, therefore, a great variation in the terms of business of different computer manufacturers and this variation is indeed sufficient to make equipment, which on the face of it appears to be more expensive, in fact cheaper in the long run, because the basic charges made include some, and in one instance, all of those mentioned above.

Additional Costs

Some expense must be incurred to decide whether there is in fact a case for studying further the possibilities of profitably installing a computing system. This will generally be done in one of two ways. Either the user concerned will have one or more of his staff trained to advise on computing systems and the cost of this training will probably represent something in the order of £1,000. This individual will then be in a reasonable position to give an opinion, but this is bound to be somewhat biased by virtue of his direct connection with the organisation.

Alternatively, the potential user could call in a specialist consultant to give an opinion and this usually is a much cheaper way of approaching this particular aspect of the work.

If there is a superficial case for a computer then, provided there is a reasonable chance of a sale, some computer manufacturers will undertake surveys to varying degrees so as to ascertain more precisely what they feel should be done. They can then make detailed recommendations which can be considered by the prospective user.

Staff Requirements

If the user is to consider these suggestions seriously, then he must either give his own staff more training or again call in a specialist consultant.

If the user is finally going to install a computing system, he requires special staff to deal with the installation. Sometimes this staff can be recruited from within the organisation itself and could well be made available as a result of staff saving when the installation is in operation. There is, however, an interim period which could last from as long as two to four years, during which the installation is being planned and installed and during this time the staff would generally be fully employed on their existing duties. They could, obviously, not carry out their existing duties as well as devote the necessary time towards planning the computer installation and to try to deal with this phase of computer work on a part time basis, is a very hazardous operation.

The main requirement of those who will be in charge of an installation is not so much a knowledge of computer techniques as a real knowledge of their own organisation. This point supports the employment of staff from within the organisation itself, even at the expense of their having to be replaced in their existing work by the recruitment of new staff. If the user's own staff are of the right calibre then they can be trained in specialist computer knowledge to meet their various needs. Some of this training is of a general nature which applies to all computers, but it is best if the training given to them can be of a specialised nature concerning the actual equipment which they

are due to use. This of course means that the equipment has to be chosen first.

Originally, computer manufacturers were able to offer considerable assistance with the planning of systems and the actual programming, but as more and more demands are being made upon computer manufacturers' staff, it is likely that in the future this assistance will not be so readily available.

To offset this, manufacturers are developing automatic programming techniques which will enable assistance to be given in the actual coding, once systems have been designed. These techniques in no way supersede the system designing required, this being the major part of the work.

A possible compromise on this initial work is to rely to a fairly large extent upon the employment of computer consultants up to the stage when a system is actually chosen. Once this stage has been reached, the user must make provision for suitable trained staff to handle his installation, possibly initially with the assistance of the computer manufacturer's staff; but with only a requirement to train them in the use of one manufacturer's equipment, instead of having to dissipate their efforts over a much wider field and obtain knowledge, at considerable expense, which may never be made use of.

Costs of Stationery

The provision of new stationery and the designing of forms etc., for use with the new system presents difficulties in addition to the actual financial questions raised. Usually the installation of a computing system if it is to be a worthwhile operation, involves a considerable measure of integration and this inevitably means the breaking down of existing department barriers and the redesigning of both procedures and the paper associated with these procedures.

Redesigning forms on the scale which is sometimes necessary cannot be done quickly and requires careful thought and study.

This aspect of the work may take two to three years, during which period one would normally expect changes to be made in the organisation and method procedures as they existed originally. It is undesirable that these new forms should be used for only a short period of time, and the ideal solution appears to be to ensure, if procedures have to be changed as an interim measure, that the computer study team assists in the redesigning of the forms in such a way that they can later be used in the computer system without change, but also leaving them capable of being used for the time being with the existing system.

If this approach can be used then it will materially assist the changeover and it does not of necessity mean that although forms are being redesigned on this basis, that a computer will be installed. In fact work of this sort can be done for some time, during the decision taking period, without committing the organisation concerned to the purchase of a computer.

The fact must be faced that it is extremely unlikely that an effective commercial computing system can be installed for even a small organisation for less than £100,000. If the organisation concerned is a reasonably large one then it is probable that the cost will be at least twice or three times this figure. However, there are at present in Britain a small number of very effective computer installations, which are rapidly proving both economic and worthwhile investments.

Finally, there does not appear to be much of a general case for installing many large computing systems in Britain. The emphasis is likely to be on the medium sized system.

Electricity supply controlled by computer

TO produce electricity for a metropolitan area at minimum cost the Philadelphia Electric Company are to use a digital computer. Collaborating with Philadelphia Electric in the launching of this digital computer-directed system in the electric power industry are the American associates of Honeywell Controls Limited, Greenford.

The system will calculate the least expensive pattern of allocating generation to meet system demands, automatically assign this allocation to generating units and provide cost data for billing computation on the power exchanged with neighbouring electric companies.

Primarily, the system will determine the economic allocation to Philadelphia Electric's generators of the total power required by the Pennsylvania-New Jersey-Maryland inter-state grid system.

To do this, the computer will use information stored in its memory of such factors as transmission line losses and production costs for each generator. Simultaneously, it will read data constantly being fed into it by control instruments and make use of other data in making control computations.

Using equations, the computer will then determine how much generation is to be produced by each generating unit under automatic control.

These digitised computations will be converted to analogue signals and telemetered as commands to load control devices at the generating stations. There the commands will be apportioned among generators to produce the required power at the correct computed cost.

Basic interconnection cost data will be determined by the computer as a secondary function. This data will be used for accounting purposes on power exchanged over the tie lines between Philadelphia Electric and five neighbouring companies.

Information showing power flow in either direction will be received from tie-line connections as analogue signals. The computer will convert this data to digital form, integrate the flow, make a cost determination from information previously programmed into it, and punch out its computations on paper tape for further processing. Most accounting data is now assembled manually by power companies.

Operation of the computer-oriented load control system will be directed from a console in Philadelphia Electric's Load Dispatching Office in central Philadelphia.

BTH Systems Laboratory — control room showing operating consoles and control gear. On left can be seen display instruments for demonstration and training purposes

BTH Systems Laboratory

In order to develop and test aircraft electrical power components and power systems to the fullest extent and to the relevant British and American specifications, at first individually and then combined in a complete power system, BTH has built a new laboratory at Coventry to supplement existing laboratories at both Coventry and Rugby. The new Systems Laboratory has been designed particularly for the testing of constant-frequency power systems, and is capable of handling a four-channel system with 60 kVA per channel at power factors of 0·75 and 0·8.

Two of the four running stands have been specially designed for starter-alternator development. These stands are capable of testing the starting characteristics of the alternator, and are finally switched over to drive the alternator as on an engine installation.

The soundproof control room contains 10 consoles which control motor-generator sets supplying the driving motors and all the necessary air and oil supplies for the alternator on test.

A load system is provided for each of the four channels, each load being divided into two quarter- and one half-load units, selected by push-buttons at the consoles. These load units are adjusted to represent quarter and half full-load at 30 or 40 kVA and at 0·75 or 0·8 power factor. The "fifth" load, which may be coupled to any of the other four, or used independently, has one section which is identical with each of the other four, so any channel may be loaded up to twice full-load at 0·75 or 0·8 p.f. This load unit also provides loads up to full load at unity power factor as well as 30 or 40 kVA at near zero p.f. An unbalance unit may also be switched in to give up to $\pm 20\%$ unbalance on two lines, and is infinitely variable so that the system may be taken through balance smoothly. Finally, a contactor is installed to enable the whole system to be short circuited.

The resistive elements of the loads are low temperature coefficient grid-type resistors which are air-cooled. Air-cored inductors are used for reactive loads to avoid waveform distortion. Air for cooling the driving equipment and resistive loads is supplied at the rate of 30,000 ft³/min.

A set of main instruments is displayed at one end of the control room. These are used for demonstration purposes and for the training of airline personnel in the operation and adjustment of aircraft systems.

The driving rigs for the alternators are rated at 70 h.p. continuously at speeds between 3,000 and 10,000 r.p.m. at the alternator and up to 120 h.p. for short periods.

The control of a rig and the loads on the alternator is from either one of two consoles, the rigs and consoles being colour coded for identification (this also applies to the display panels).

The instruments on the consoles show line volts, line currents, watts, vars and frequency for the alternator, driving motor d.c. input, and rig speed. The display panels show the line volts, amps, watts, vars and frequency, and rig speed for each channel.

About six miles of cable were used in wiring this laboratory.

Work now in progress is centred upon the development and testing of a.c. constant-frequency systems for civil airliners, involving the latest designs of power system components such as magnetic-amplifiers, potted and hermetically-sealed units, silicon rectifiers, brushless alternators, and all forms of switchgear and protective relays.

Circle 53 for further information

A completely **NEW** ¢

miniature **IN-LINE** digital display unit

Here is the latest in projection type read-outs featuring one plane presentation. All figures, characters or letters appear on the front surface of the unit and are uniform in size and intensity. In addition to being easier to read the information may be quickly seen from a very wide angle of viewing. Designed as a single unit the In-Line Display may be assembled in any desired grouping presenting a continuous surface for fast and easy reading.

Write for full details

Single unit—actual size

Illustration shows a bank of 4 units (approximately half full size)

OUTSTANDING FEATURES

- ★ **Figures, characters or letters are $\frac{5}{8}$ in. high by $\frac{7}{16}$ in. wide.**
- ★ **Unit provides 12 light channels.**
- ★ **28 volts operation.**
- ★ **Standard model displays 0-9, decimal point and coloured background.**

STOP PRESS
Decimal Coded Binary Units are being developed

Counting Instruments Ltd

COUNTING INSTRUMENTS LTD., 5 ELSTREE WAY, BOREHAM WOOD, HERTFORDSHIRE.
Telephone ELStree 1382 (4 lines)

INSTRUMENT Practice
AUTOMATION & ELECTRONICS

SURVEY
OF NEW INSTRUMENTS

ELECTRICAL · ELECTRONIC · MECHANICAL · NUCLEONIC · PNEUMATIC

Machine Tool Control System

E.M.I. ELECTRONICS LTD. have developed a new machine tool control system designed to meet the needs of the small batch producer, giving improved production efficiency for a small capital outlay.

This system is fitted to a specially designed co-ordinate table which operates on recirculating ball slides and is actuated by hydraulic cylinders, for which the high pressure oil supply is derived from compressed air.

The control system employs the basic principles of the other EMICON electronic positioning control systems. The fine measuring element is the EMICON general purpose inductor having an electrical accuracy of $\pm 0{\cdot}0005$ in.

The control system and co-ordinate table are arranged as an integrated equipment which may be applied to a drilling machine of suitable dimensions and spindle quality. The table is automatically locked as soon as the working position is reached and, where the facility exists on the machine, a signal may be provided to actuate the spindle feed when the table is in place. The machine would thus proceed automatically through a complete drilling programme.

Information can be fed into the control system in the form of 5 hole teleprinter tape, or alternatively may be set up on dials for manual operation.

Circle **1** *for further details.*

Elevating Trolley

"SKYSORLIFT" is the name of a new hydraulic elevating trolley just produced by Farrow and Jackson Ltd. An inclined or horizontal hydraulic ram, lifting heavy duty metal scissor guides, through cams and rollers, provides a strong, positive and smooth action elevating trolley, suitable for long periods of heavy work.

"Skysorlift"

The lifting mechanism is actuated by either a foot or hand operated pump, the pump unit being provided with a release valve that allows for smooth and controlled descent. The minimum lowered height is 9 in. and a varying range of lifts can be supplied to suit individual problems and applications.

The "SKYSORLIFT" is fitted with either four swivelling wheels or two fixed wheels and two "stillage" type feet and standard "tug-lift". Individual wheel braking is also incorporated.

Tops can be fitted to suit requirements. Sheet steel table tops are normally supplied as standard.

Circle **2** *for further details.*

Small-bore Measuring Equipment

SMALL-BORE measuring equipment introduced by Hilger & Watts for attachment to a microptic horizontal measuring machine TL.10 (metric scale machine TL.11) is designed to measure small-bores from 0·04 in. to 0·5 in. (1 to 12·7 mm) in diameter, to an accuracy of 0·00005 in. (0·001 mm).

The equipment consists of an arm carrying a probe, a cross-traverse work table fitted with a micrometer which reads to 0·001 in. and a mains-operated electrical unit which controls a magnetic brake device attached to the measuring plunger of the machine.

To measure a bore, the arm is attached by a spigot and threaded ring to the machine's measuring plunger, with the probe in a vertical position. The workpiece is clamped to the work table which is then raised so that the probe enters the bore. The measuring plunger is then moved longitudinally until the probe makes electrical contact with the wall of the bore, which causes the magnetic brake to be applied, thereby "locking" the plunger and preventing further movement. The reading appearing on the ground-glass viewing screen of the machine is noted. The brake is released by a push-button switch and the plunger is then moved in the reverse direction until the probe makes contact with the opposite wall of the bore, when the brake is re-applied. The diameter of the bore is the difference between the two readings obtained.

To ensure that the true diameter across dead centre has been measured, several pairs of readings are taken with the work table set, by means of the micrometer, in various cross-traverse positions. The highest difference in readings is the true diameter.

A dial indicator for measuring the depth of the probe in the bore is also available.

Circle **3** *for further details.*

Solder Pins

Two new ranges of solder pins have been introduced to meet the 0·052 in. hole size recommended in B.S.S. 3081/1959 and Defence Guide 5007. Rivet or force-fit assembly for either single-ended or double-ended connections, are available.

Turned from solid brass, they are flow-tinned giving an excellent shelf life and reliable solder flow on printed wiring or in the higher densities of present day conventional circuits.

Circle **4** *for further details.*

Pneumatic Cylinders

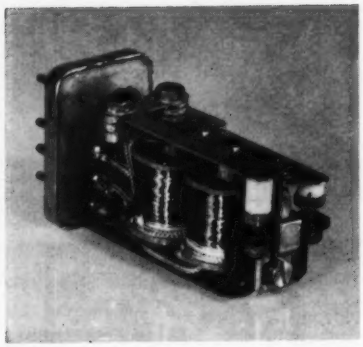
To meet the ever-increasing demand for a robust, small bore cylinder of light construction, Baldwin Industrial Controls have introduced three new basic cylinders to their range. Bore sizes are $\frac{3}{4}$ in., 1 in. and $1\frac{1}{4}$ in. with strokes ranging from 1 in. in the $\frac{3}{4}$ in. bore size to 10 in. in the $1\frac{1}{4}$ in. bore. Cylinders can be either double acting or single acting with spring return.

These cylinders have been designed primarily for light holding, clamping, or similar jobs where small physical size combined with rugged construction are first considerations.

Maximum air pressure is 150 p.s.i., delivery is ex stock and prices range from 19s. 6d. each.

Circle **5** *for further details.*

Small bore pneumatic cylinders



Low current switching relay, without cover

Low Current Switching, Miniature High Speed Sealed Relay

A LOW current version of an existing miniature high speed sealed relay has been developed with an activated carbon getter inside the container to adsorb the slight organic vapours that remain after sealing which lead to contact contamination.

Known as the Type 130, it is particularly suitable in its special version for use as a "chopper" for converting low power d.c. signals into alternating voltages, as required for amplification in computers; and has application in other circuits where control of low currents in microamps is required.

Of the single changeover type, the relay is made for various voltages between 1·2 and 48 volts d.c. Typically, the contacts might be used to switch 25 millivolts at 1 microamp. These contacts are of platinum, and contact resistance is 0·1 ohm or less.

At 100 operations per second the relay has a life of 300 hours minimum, though 5,000-10,000 hours are usual; a recent continuous life test showed approximately 3,600 million operations.

Inorganic materials have been used throughout where possible and manufacture is carried out in dust-free conditions.

Weighing under $2\frac{1}{2}$ oz, the Type 130 relay measures $2\frac{1}{8}$ in. $\times$ $1\frac{1}{16}$ in. $\times$ $\frac{3}{4}$ in., terminal pins extending $\frac{9}{32}$ in. beyond the length dimension. A plug-in base is an optional addition.

Circle **6** *for further details.*

Polaroid Films for Series 400 Camera

Two new Polaroid films are now available for the Thompson-Land Series 400 camera.

Polaroid film, Type 46L, produces black-and-white transparencies $3\frac{1}{4}$ $\times$ 4 in., ready for viewing in two minutes after exposure. This film has a rating of 1,000 ASA in daylight, or 700 ASA in artificial light. The inherently high definition and high contrast of the emulsion, coupled with its speed, makes this film particularly suitable for oscilloscope photography. The finished transparency is practically dry when it is removed from the camera and can therefore be mounted and projected at once. It is, however, essential that each transparency is treated in a Polaroid "Dippit" within an hour of exposure to harden the emulsion and prevent discolouration; otherwise, the procedure is the same as for the standard film.

Film, Type 44, is a normal Polaroid film with a rating of 400 ASA in daylight, or 280 ASA in artificial light, producing ordinary black-and-white prints in one minute after exposure. This increase in speed has been achieved without loss of print quality or image definition; it will, therefore, supersede the existing Type 42 when present stocks are exhausted.

Circle **7** *for further details.*

"Sterimag" Low Power Stereoscopic Magnifier

THE microscope head is fitted to a substantial long arm stand with heavy base. The optical head is fitted with a swivel joint so that it can be used in an inclined position, and the instrument can be bought with a built-in spot lamp, run off a transformer housed in the base.

Two models are available, one with a magnification of $\times$20 which has a field of view of 10 mm diameter and one of $\times$10 magnification with a field of view of 20 mm. Large objects can be examined by moving the microscope over the object. Each has a free working distance of approximately 7 inches from the object to the microscope head.

The "Sterimags" are useful in production inspection to examine cutting edges; in floor inspection for quality control; for assembly of small components, e.g., valves and small electronic assemblies, and for mounting on machines for observing delicate operations.

The object is seen magnified, right way up, and in stereoscopic relief, with good depth of focus.

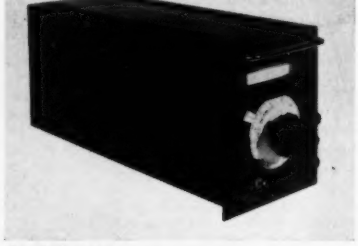
The price of either model with built-in spot lamp is: £34 0s. 0d.; and without spot lamp: £30 0s. 0d.

Circle **8** *for further details.*

Fault Detector for High Voltage Power Lines

AN electronic fault detector has been developed by Ferranti Limited of Edinburgh in co-operation with the North of Scotland Hydro-Electric Board to facilitate rapid location of faults occurring on 132kV grid lines.

The types of fault that can be expected fall into three broad categories: latent, sustained and transient faults. An example of a latent fault is an impaired ground clearance of a conductor, which will not cause flashover at normal voltages. A sustained fault can be produced by a broken conductor or a badly damaged insulator string. A transient type of fault occurs when lines clash during a high wind, or lightning strikes the line. The North of Scotland Hydro-Electric Board have one type of fault which commonly occurs during the winter, namely, ice accretion on the lines. This commences as a latent fault since the conductors merely sag. It eventually develops into a sustained fault when the conductors sag sufficiently to touch the ground or each other.



Fault detector

The type of fault locator chosen by Ferranti Ltd., to deal with these problems, was the so-called radar type locator. This locator works on the radar principle of pulse reflection, the reflection in this instance being caused by any local variation in line characteristic impedance. The distance to the fault can be found by measuring the time interval between the sending of the pulse and the reception of its reflection.

Radar type locators can be divided into two classes, i.e., d.c. and a.c. In the d.c. type, direct connection is made between the line and the locator. This means that this is a "dead line" type of locator since it cannot be connected to a live line. It can, therefore, only detect sustained faults. The a.c. locator is coupled a.c. fashion to the live line, through some suitable coupling device, which is usually the coupling capacitor used with the carrier control system. This type of locator can detect transient faults at the expense of increased complexity. D.c. locators usually tend to be portable devices, whilst a.c. locators, due to coupling difficulties, usually have to be permanently sited at sub-stations.

The d.c. locator is restricted in the type of fault that it can detect so further development is proceeding on an a.c. type locator.

The technique to be used for the detection of transient faults involves leaving the equipment normally in a standby condition and switching to the operating state in the few milliseconds, between the detection of a fault by the normal line protection equipment, and its clearance by the operation of the circuit breaker.

Circle **9** *for further details.*

Air-operated Controller

TAYLOR CONTROLS have introduced a new air-operated controller.

It is furnished in two models, adjustable proportional response with adjustable band between 1% to 30%, and fixed high response.

The proportional band is adjusted from inside the case by a Perspex knob which magnifies the proportional scale, which can be seen through the door aperture. An air output gauge is included as a standard feature for checking performance.

The action is either direct or reverse and is changeable on site without extra parts. The air relay valve is of the non-bleed force balance type, which gives a large output capacity with low air consumption. For adjusting the control point, a knob is turned inside the case.

A wide range of standard scales is available graduated in temperature or pressure, with equivalent metric units on the same scale.

Air-operated controller

Temperature actuation is by mercury or vapour tube system, with a large range of bulb fittings, and pressure by multi-coil Bourdon spring in bronze, steel or stainless steel.

Controller casing is die-cast aluminium with chromium door handle and rubber sealing gasket. Size 11¾ in. wide by 8¾ in. high by 3½ in. deep.

Case is standard for both flush and surface mounting or can be mounted directly on a control valve diaphragm head.

Circle **10** *for further details.*

Ventilating Fan Protection

THE ACCURATE RECORDING INSTRUMENT COMPANY have developed a system of ventilating fan protection applicable to coal mining, and is designed to prevent breakdowns in the event of bearings overheating, loss of air in the pit due to low fan speeds or falls in the workings.

The principle of the temperature measurement of the bearings is the liquid expansion system as applied to the indicating thermostat. A rise in temperature at a bearing measuring point (normally in the oil reservoir) causes a bellows to operate a micro-switch (capable of 10 amperes at 250 volts), which in turn closes a visual lamp and audible alarm circuit, thereby drawing attention to any attendant that the particular bearing has reached a temperature likely to cause a breakdown of that bearing. The audible alarm may be silenced, but a flashing lamp is immediately switched on showing that alarm conditions exist. This lamp and that associated with the bearing will remain alight until action has been taken to restore conditions to normal. The preset point at which the alarms come into circuit is infinitely variable over the whole of the instrument scale range, by means of a special key, and is normally set some 5 to 10°F above the normal working temperature of the bearing. If, however, the temperature of the bearing should continue to rise, a second switch is operated which in turn will cut the mains supply to the fan motor, thus stopping the fan and avoiding further damage.

The instrument is fitted with a third micro-switch which is operated in the event of the instrument becoming unserviceable through any known cause, thereby providing a fail safe system.

The whole of the thermometry is of the fully compensated type and is not affected by changes of ambient temperature on long lengths of capillary, or at the instrument head.

The draught gauge recorder measuring the air pressure in the pit is fitted with high and low contacts which are variable and normally set at some point lower and higher than the normal. Should a variable condition occur, one of these contacts will cause a visual and audible alarm to be made as in the case of the bearing temperature.

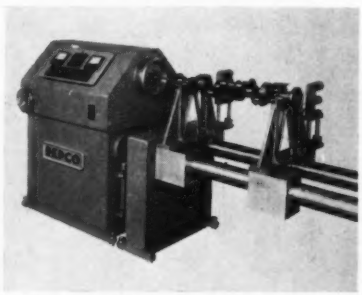
The whole of the visual and audible alarms may be transmitted to a small remote supervisory panel up to a considerable distance, together with precise readings on a 6 in. indicator of the water gauge suction conditions. This means that the more important functions of the system may be located at a remote point and can be under the supervision of persons doing another job.

The fan belt alarm operates into the common visual and audible alarm circuit and is designed to bring to the notice of the persons responsible the fact that a belt is about to break or has broken.

Circle **11** *for further details.*

Crankshaft Balancing Machine

THE crankshaft is spun in a bearing at either end, and is driven through a flexible coupling. Each bearing is carried on a light aluminium support, this in turn being attached to the crankshaft balancing machine by flexures providing easy, undamped movement.



Electronic crankshaft balancing machine

Both bearing supports are connected by light rods to magnetic pick-ups, which convert vibratory movement into electrical impulses. These are amplified electronically and fed into a cathode ray tube, which indicates by the circular trace produced, the source of vibration. A meter indicates its magnitude, and thus the amount and location of metal to be removed from the counterweights to correct the unbalance is known.

In practice, the circular trace makes the determination so simple that tests are quickly made even by operators with no special training. The sensitivity is such that a displacement of 0·000025 in. due to vibration is measured, which is equivalent to unbalance within 0·002 ounce inch per 10 lb of rotor weight.

Standard machines have motors variable in speed between 400 and 4,000 r.p.m., while others have 3 speeds of 650, 1,100 and 2,200 r.p.m. They can take rotors up to 200 lb. Special machines are designed for rotors varying from a few ounces to several tons.

Simpler machines for balancing in only one plane are used for disc-like structures such as clutch plates. These utilise a stroboscopic light to locate the heavy point and are usually constructed with a vertical drive shaft.

Circle **12** *for further details.*

Low Voltage Power Supply Unit

THE LS353-H supply unit is intended for use in situations requiring a compact, stabilised d.c. source such as heater supplies in d.c. amplifiers, exciter lamps in photo-electric measuring instruments and other applications where batteries are normally used.

The basic unit is a germanium junction rectifier circuit with a transistor voltage stabiliser and a reference potential device.

The system described above is a development of the "Altron" constant potential chargers supplied for use with "DEAC" mercury-cadmium, hermetically sealed accumulators. "DEAC" chargers are available for a range of voltages from 1·5 V to 24 V and currents up to 100 amperes or more.

Supply units are available either in chassis form or in cases.

SPECIFICATION:

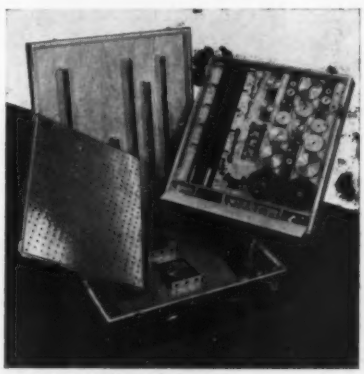
Nominal voltage	— 6·3 V	
Stability against mains variation of ±10 volts	— +25 millivolt	
Full load ripple	— less than 3 mV r.m.s.	
Mains supply	— 190 to 260 V, 50 c/s	
Dimensions (chassis model)	— 4 × 10½ × 6⅝ in.	10·1 × 27 × 15·7 cm
Weight	— 7½ lb	3·4 kg

Circle **13** *for further details.*

Servo-system Assembly Kits

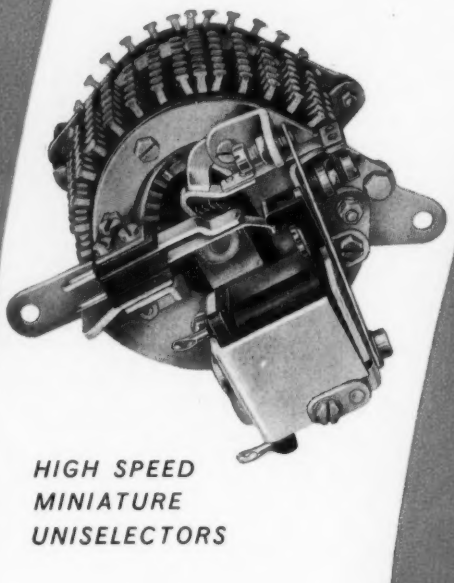
FEEDBACK LTD., in association with Servomex Controls Ltd., are manufacturing kits that are designed to provide for the rapid experimental assembly of precision servo-systems by the use of pre-assembled and accurately finished components. These components are designed to simplify and overcome assembly problems that may be met in the course of servo-system experimentation. They will allow students and engineers readily to assemble working electro-mechanical systems themselves, using only hand tools, and without the help of technicians trained for the precision fitting of components.

The units are simple and flexible; the synthesis of a system involves merely setting up various components in their



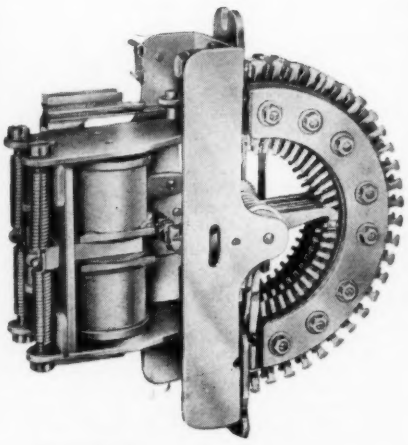
Servo-system assembly kit

Circle 54 for further information

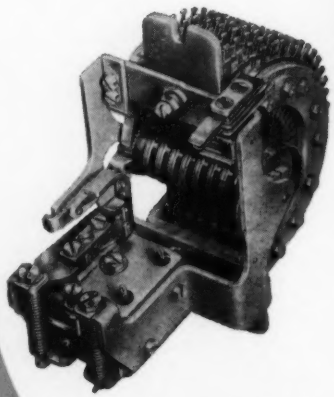


HIGH SPEED
MINIATURE
UNISELECTORS

TENSION
GAUGE



BOTHWAY
UNISELECTORS



HEAVY DUTY
UNISELECTORS

G.E.C. Uniselectors

For full details of all G.E.C. Apparatus for Stepping and Controlling Applications please write to:-
THE GENERAL ELECTRIC COMPANY LTD · OF ENGLAND
TELEPHONE · RADIO AND TELEVISION WORKS · COVENTRY · ENGLAND

G.E.C. 43

correct places on an accurately-machined rigid base plate.

The principal units of a standard kit consist of 23 32 D.P. 20° pressure angle, Admiralty instrument quality gears, available in range 12 to 120 teeth, component mounts for most standard servo-motor fittings, bearings, flexible couplings, cams, etc.

The units are sold as a kit, or separately.

Circle **14** *for further details.*

Differential Pressure Transmitter

THIS mercuryless force balance differential pressure transmitter is 6½ in. long by 3 in. diameter, and weighs 4½ lb.

The operation is pneumatic, a 3 to 15 p.s.i. signal being transmitted with an accuracy of 1%, covering ranges 0 to 50, 100, 200 and 300 inches of water.

Because of low original cost and economical installation and maintenance, the practicability of flow measurement is now extended to many jobs previously considered marginal and uneconomical, e.g., the metering of steam, water and air to a given department for cost accounting purposes.

Some of the features are:

Simplified piping because it can be close-coupled to orifice flanges.

No seal pots required. Negligible displacement because of force balance construction.

External zero and range adjustments.

Self draining or venting—no periodic manual venting or draining.

Over-range to full working pressure (150 p.s.i.) with no permanent damage.

Compact, weather-proof. Built for rough service and outdoor mounting.

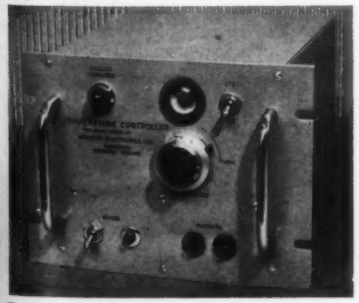
During operation, the measured fluid received in the process side of the transmitter, exerts a force on the sensing diaphragm proportional to the differential pressure. This force moves the stack, establishing the distance between baffle and nozzle. The baffle-nozzle relation determines the transmitter output air pressure, which is also the feedback pressure against the stack.

With an increase in differential pressure, the baffle approaches the nozzle. The resulting increase in output air and feedback pressure forces the stack back to its approximate original position.

Circle **15** *for further details.*

Temperature Controller

A PLATINUM resistance thermometer forms one arm of an a.c. powered Wheatstone bridge, the pre-set arm of which consists of a 1,000 ohm potentiometer graded in steps of 0·25°C.



Temperature controller

The out of balance voltage from the bridge is amplified by a two-stage amplifier giving a gain of approximately 2,000. The amplified output is also fed to a phase sensitive bridge, which gives a positive or negative output according to whether the furnace temperature is lower or higher than the correct setting. This output is amplified 10 times by the d.c. amplifier and then applied to one section of the relay controlling the furnace relay. A time interval generator provides switching cycles of, normally, 30 seconds to the other section of the relay control, which is so connected that the first section conducts, thus energising the relay only when the control signal from the thermometer is more positive than the signal from the time interval generator. When the furnace is at the correct temperature, the relay is energised for one half of the time cycle. The switching of the furnace relay is used to alter the furnace current between two values chosen to match the furnace characteristics.

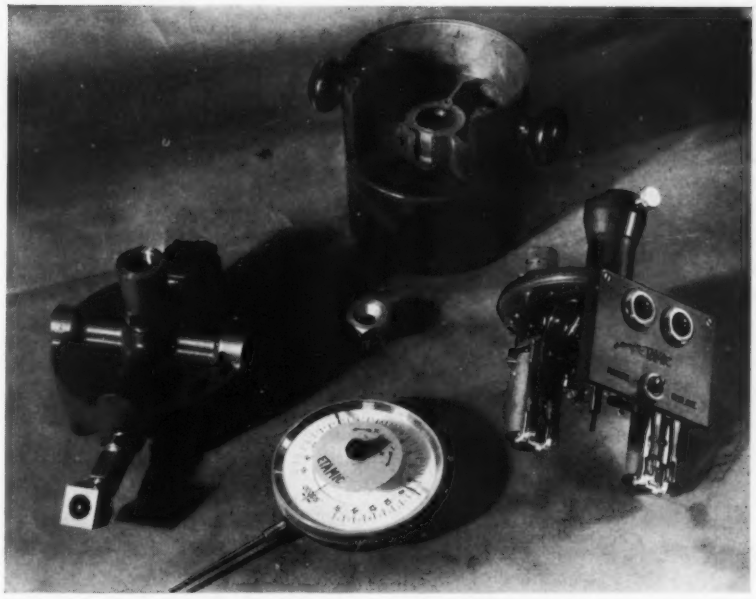
SPECIFICATION:

Range	— Any desired range up to the limits of a platinum thermometer, i.e., 1,200°C. A direct calibrated range of 1,000°C in 0·25°C steps is provided
Proportional Band	— 25°C with 12AX7 for Valve 1 10°C with a 13D3 for Valve 1 30°C with a 12AU7 for Valve 1
Supply	— 200/250 or 100/130 volts a.c. at 40/100 c/s

Circle **16** *for further details.*

Air Gauging and Size Control Equipment

THE basic "ETAMIC" gauging unit consists essentially of a pneumatic control head which incorporates a high pressure system, providing air flow at constant sonic speeds through a needle valve and diaphragm used in conjunction with a true pneumatic Wheatstone bridge. Design of the system, which has eliminated the need for flow regulators or pressure gauges, permits deviations from accuracy of ± 0·000006 in. to be detected.



Air-gauging and size control equipment
Top: Die cast body
Left: Diaphragm and needle valve housing
Bottom: Dial gauge covering a range of ±0·0016 in. with 0·00005 in. divisions
Right: Relay unit which operates signal lights, or effects control of a machine tool operating cycle

A recent development of the makers has been to associate the gauging element with a relay unit to establish an automation head.

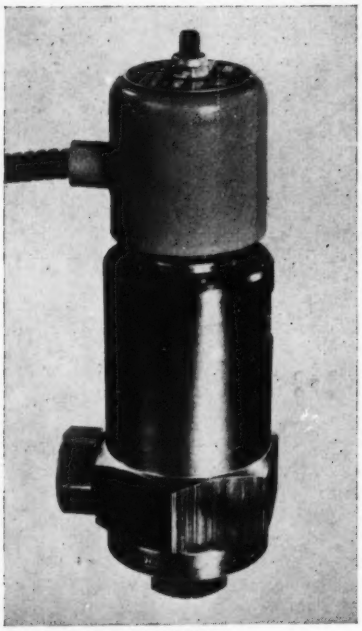
The automation heads may be used singly for normal gauging purposes or in a bank for multiple inspection purposes; in the latter case mechanisms can be supplied for loading, acceptance and rejection of components.

An alternative application for which design features and robust construction of the unit make it eminently suitable is in size control of components produced on a variety of machine tools. In the case of grinding machines the head will control the size of workpiece diameters to within 0·00002 in.

Circle **17** *for further details.*

Solenoid Valve Type ASV

SOLENOID valve Type ASV is designed for use in systems where an auxiliary pressure supply can be used to actuate a servo device controlling the main valve. The auxiliary supply is controlled by a small three-way pilot solenoid-operated valve which, when it is energised, allows pressure to operate on a piston, which is integral with the main valve seating assembly. There are two models; on one, pressure is applied to the top of the piston and the main valve closes when the pilot valve is energised; on the other, pressure is applied to the underside of the piston and the main valve opens when the



Solenoid valve type ASV

pilot valve is energised. Main valve sizes up to 1 in. are available at pressures up to 500 p.s.i. depending on the auxiliary pressure supply available.

Circle **18** *for further details.*

Plante Sealed Cells

A NEW RANGE of stationary cells is announced by Pritchett & Gold and E.P.S. Co. Ltd., consisting of high performance cells of the Plante type in sealed glass boxes.

These cells are suitable for any type of stationary duty not requiring substantial discharges more often than about once a fortnight: they are recommended for trickle charging, floating, or conditions not requiring frequent cycles of discharge and recharge.

Special features of design result in a saving of up to 50% in space compared with a standard stationary battery made to B.S. specification.

The cells are built to give a long trouble-free service and embody Plante positive plates of a large developed area and negative plates of a lattice grid design. The positive plates are supported on shoulders moulded in the glass box and the feet of the negative plates rest on a rigid support in the bottom of the box. Buffers moulded in p.v.c. are fitted between the end negative plates and the container walls to give a tight assembly of the complete cell.

Separators are of Porvic, a microporous plastic. The use of Porvic separators has enabled the plate pitch to be reduced without likelihood of short circuits developing.

The glass box has insulator feet moulded externally, but for batteries of more than 75 cells separate insulators are provided. The range comprises 14 P. & G. high performance cells in capacities ranging from 15 Ah to 400 Ah at the 10 hour rate of discharge. For loadings which demand it the terminal pillars are copper-cored and the cell to cell connectors are of lead plated copper. The cells are supplied fully assembled, and for use in the British Isles they are despatched filled with acid and fully charged ready for service.

Circle **19** *for further details.*

Portable Potentiometer Recorder

A LIGHT-WEIGHT, self-contained recording instrument with a power driven pen is available for use in automobiles, heavy vehicles, aircraft, marine craft, or in any location where mains supplies are not available. It is mobile and portable.

It is battery operated and weighs only 10 lb.

The recording chart has a width of 4 in. and is driven by a clockwork motor which can operate continuously for eight days.

Whilst particularly suitable for temperature recording it can also be supplied with a range of input circuits for such differing purposes as pH recording, weight recording (using electronic load cell) or wind recording. It can also be used in conjunction with the Mervyn-WPRL Polarographic Electrode for dissolved oxygen recording.

The transistorised chopping system has no moving parts, and the chopping is done at 1,000 c/s, thus minimising difficulties of 50 cycle interference. The all-transistor amplifier uses a printed wiring board. The motor-drive for the potentiometer is by permanent magnetised d.c. motor.

The internal power supply, with batteries lasting over 250 hours in normal use, eliminates the need for a connection to the mains. For static operation, such as building into consoles, control panels, etc., mains connections can, however, be supplied if required.

Voltage reference is derived from a Zener diode.

SPECIFICATION:

Battery operated

Size	— 7 in. × 7 in. × 10 in.
Weight	— 10 lb
Panel cut out	— 6 in. × 6 in. (proposed World Standard)
Batteries	— 2 × PP11 cell
Battery life	— 250 hours normal use
Chart width	— 100 mm (4 in.) (proposed World Standard)
Chart speeds	— 1/25 in. per hour to 6,000 in. per hour
Chart indication	— Wax paper or ink
Pen speed	— 3 seconds full scale travel
Ranges	— 0·5 mV to 0·1 volt by interchangeable unit
Accuracy	— Better than 0·5%
Zero suppression	— Up to 4 times span or 0·8 V whichever is the smaller
Cold junction compensation	— For all common thermocouple materials
Proof stress of measuring circuit	— 500 V

Mains operated

Power consumption of internal power supply	— 10 watts
Voltage	— 26 - 250V a.c.
Frequency	— 50, 60, 400, 1,600, 2,400 c/s

Circle **20** *for further details.*

Oil Burner Sequence Controller

A NEW fully automatic oil burner sequence controller combined with flame failure control and self-checking circuit gives a safety control for all types of oil burners.

Using a photo-resistive photocell capable of operating the contactor direct and a synchronous motor timing device this new unit ensures accurate repetitive timing cycles and has eliminated the need for valve amplifiers or magnetic amplifiers and bi-metal controls.

The photocell is normally mounted in the blast tube of the burner but housings are available for mounting on the front plate of the boiler if required.

The control circuitry has been designed to fail to safety under every condition, for example:

(a) A safe start relay is incorporated to ensure that the photocell is in darkness when the thermostat calls for heat. If the photocell has been left out in the open at this point the unit will not start up and an external warning bell will be energised.

(b) Should the cell leads short then the unit will not start up and the warning bell will be energised.

(c) Should the time clock cut off the supply whilst the motor is moving through the oil period then on re-establishment of the supply the motor will continue its cycle without bringing on the oil and will start a new cycle at the correct time.

(d) Two purge periods have been incorporated—the first at the commencement of the day's operations to ensure a clear boiler and the second from the lockout position to the re-commencement of a new cycle.

All time periods can be varied to suit any type of burner and to comply with L.C.C. and B.S.I. specifications.

In the case of heavy oil burners where a purge of the oil line is required then an additional cam and switch can be incorporated to energise the solenoid valve for a pre-determined period for this operation to be performed automatically with this same unit.

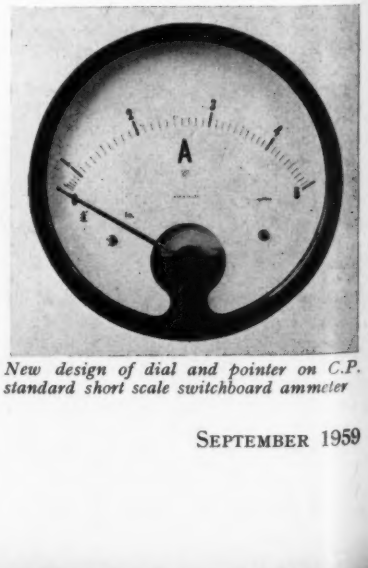
Supply voltage 200/250 V, a.c., single phase, 50 cycles. Power consumption 15 watts. Price £19 10s. 0d. retail. Delivery 3-4 weeks.

Circle **21** *for further details.*

Switchboard Instruments

A COMPLETELY new design of both dial and pointer on their standard short scale switchboard instruments has now been adopted by Crompton Parkinson Ltd.

The circumferential lines on the scale have been dispensed with and a plain bar



New design of dial and pointer on C.P. standard short scale switchboard ammeter

takes the place of the old spade shape pointer.

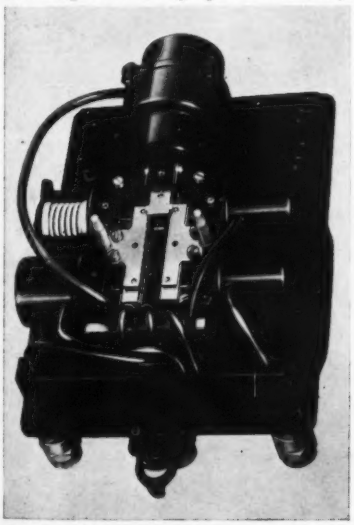
The result of these changes is an instrument scale which is very easy to read and is in keeping with the latest trends in industrial design.

Circle **22** *for further details.*

Flow Measurement with Automatic Pressure and Temperature Compensation

THE size of an orifice plate for measurement of gas flow is calculated for one temperature and one pressure; it follows that any variation in either will affect the accuracy of the final reading. In most cases variations are small and the effect on metering accuracy is negligible. However, instances do arise in which large changes in either pressure or temperature, or both, are encountered and it is then necessary to apply a correction.

Honeywell Controls Limited are now able to supply a system providing automatic compensation for either temperature or pressure, or both—using the Sorteberg force bridge pneumatic relay.



Sorteberg force bridge

This is essentially a multiplying and dividing unit which corrects the flow signal for pressure and temperature changes.

The pressure and temperature transmitters are calibrated from absolute zero to the maximum values for which compensation is required expressed in absolute units. Transmission is such that zero absolute is 3 p.s.i., whilst the maximum reading gives 15 p.s.i.

The flow transmitter is a standard differential converter, or similar transmitter, which does not incorporate square root extraction.

Circle **23** *for further details.*

Negative Phase Sequence Relay

WHEN unbalanced loading or faults occur in large alternators, negative sequence currents flow in the stator windings, which induce eddy currents in the rotor and the excess heat generated can cause damage. On turbo-alternators slot wedges and end bells may be detempered so that they are unable to withstand the high centrifugal stresses to which they are normally subjected.

The negative phase sequence relay has been designed to shut down a large alternator quickly before it can be damaged and also to avoid unnecessary tripping. As negative phase sequence heating varies according to the type of alternator and method of cooling, the relay has a time/current characteristic approximately matching the heating characteristics of any alternator with which it is used.

This is achieved by the provision of four negative phase sequence current settings, which give time/current characteristics from 2 to 71K ($K = I^2t$), and variable time multiplier settings.

This CDN relay is of the induction disc pattern basically similar to the type CDG inverse time-overcurrent relays. It is fed from a separately mounted negative sequence filter network.

A unit with lower sensitivity settings is also provided to give an alarm so that corrective action can be taken before the tripping unit operates. The alarm unit is followed by a time delay relay to prevent unnecessary warning on brief conditions of unbalance. It is fed from a separate filter contained in the same case as the main filter.

The disc, alarm and time delay units are all mounted in a 1½ pole draw-out case suitable for flush or projection mounting.

Circle **24** *for further details.*

Hilger D290 Grating Monochromator

A NEW, inexpensive, grating monochromator is being made by Hilger & Watts Ltd. It is intended primarily for laboratory workers, microscopists, teachers, and others, who require a simple light source of variable wavelength.

The instrument is novel in construction and uses a plane grating as the dispersing element. This grating has 15,000 lines to the inch and gives a reciprocal dispersion of 70 Å/mm. The slits, variable in width from 0 to 1 mm, are of the simple unilateral form and are so coupled that, whatever their width, the peak wavelength of the transmitted radiation remains constant. The wavelength can be varied from 200 to 1,000 mμ and is controlled by a knob with an indicator reading to 1 mμ.

The monochromator is reversible and can be mounted on its baseplate with the slits horizontal or vertical. Without the baseplate it measures only 33 × 15 × 9 cm, and the baseplate itself measures 20 × 20 × 2 cm. The total weight is 6 kg.

Circle **25** *for further details.*

Electronic Flowmeters

THE ROCHAR range of electronic flowmeters for the measurement of instantaneous rate and integrated volume of flow of liquids is now being marketed by Metrix Instruments Ltd.

The volumetric transducers employed are of the magnetic induction type and consist of a cylindrical body, through which the liquid passes, and a free rotor with helicoidal blades whose speed of rotation is proportional to the rate of flow. The alternating signal output from the transducer has a frequency in cycles per second equal to the revolutions per second of the rotor.

Rochar electronic flowmeter

The transducers are machined from heavy duty alloy designed to withstand corrosion and are satisfactory for use with nitric acid, liquid oxygen, jet and rocket motor fuels, etc. Operating temperatures from —200 to +150°C are permissible and models for use at higher temperatures are under development. The transducers are small, easy to install and are independent of vibration, position of mounting, and pressure of liquid flowing.

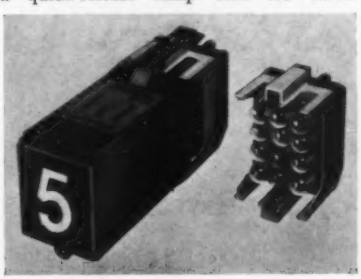
The signal from the transducer is fed into the instrument proper which consists essentially of frequency meter with a pulse shaping circuit and an output meter calibrated in terms of instantaneous rate of flow. An auxiliary circuit provides an output pulse for every complete unit of volume which is fed to a mechanical counter to indicate the total volume of flow at any time.

The range of flow rate covered is from 20 to 100,000 litres/hour and calibration can be effected in any units required.

Circle **26** *for further details.*

Aldis Digilite Projection Type In-Line Indicator A100

THIS projection indicator has increased figure size for more effective display, and a quick-release lamp unit for easier



Aldis Digilite

Circle 55 for further information

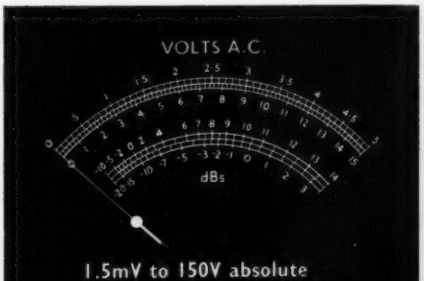
Whatever your measurement problem there is almost inevitably a precision-engineered Solartron instrument which will give you a rapid, accurate solution. Whether at ultra-low or microwave frequencies, high accuracy of indication, stability of performance and use of the most up-to-date design techniques and components characterise all Solartron instruments.

Here are just three — featured against their respective meter scaling.

ABSOLUTE MEASUREMENT

by Precision A.C. Millivoltmeter

Nine ranges: 1·5mV to 150V, f.s.d.
1% accuracy f.s.d. 10c/s to 100Kc/s.
50 megohms nominal input resistance.
Additional db scaling neg. 80db to + 34db.
Incorporates high-stability power supply.

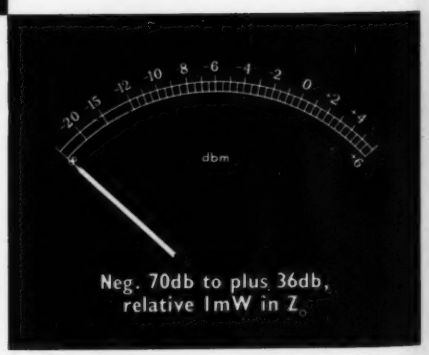


VECTORIAL MEASUREMENT

by Resolved Components Indicator

Frequency range 20c/s to 20Kc/s (0.1c/s to 1Kc/s with VP 253·2).
Direct readings in Cartesian co-ordinates plus db Reference scale.
Built-in reference system gives complete harmonic discrimination
Noise and harmonic rejection > db.
Better than 50 megohms input resistance.

Three good ways to measure



RELATIVE MEASUREMENT

by Direct-reading T.M.S.

Overall range from neg. 70 to ± 36db.
Accuracy ±0·25db 15c/s to 100Kc/s (±1db 10c/s to 250Kc/s).
For 75, 150 or 600 ohm line testing.
Balanced or unbalanced, open or terminated measurement.

Write today for full details

SOLARTRON

THE SOLATRON ELECTRONIC GROUP LIMITED
THAMES DITTON, SURREY

Tel:— EMBerbrook 5522 *Cables:—Solartron Thames Ditton*
International Telex:—23842 Solartron T.Dit

mounting and lamp change. Flush panel mounting gives a wide angle of view.

The design and method of clip fixing the lamp unit to the main body of the indicator is shown in the photograph.

SPECIFICATION:

Angle of view	— 75° off axis in all directions
Lamp	— 6·3 volts 0·3 amp
Figure size	— 1·2 × 0·6 in.
Figures	— 0-9 inclusive plus 2 decimal points, one left, one right (Standard type A100)
Overall dimensions	— Length 5·5 in. Height 3·0 in. Width 1·562 in.
Screen size	— 1·875 × 1·56 in.
Panel aperture	— 2·012 × 1·56 in.
Weight	— 9 oz or 258 g

Circle **27** *for further details.*

Automatic Tracking Comparator

INSULATING materials may form conducting tracks when subject to electrical stresses. This is particularly so when the surface is subject to contaminants like moisture or conductive dust.

The International Electro - technical Commission has specified a test to determine the comparative tracking index. This allows comparison of the susceptibility of materials to tracking.

The I.E.C. test requires that measured drops of test electrolyte are dropped at intervals of thirty seconds between two electrodes and the comparative tracking index is obtained by plotting the number of drops to cause breakdown of the material against the applied electrode voltage. The index is taken to be the voltage at which 50 drops will cause breakdown.

The automatic tracking comparator was developed to carry out the provisions of the I.E.C. specification. It employs a metering pump to deliver accurately measured drops of electrolyte at the specified rate. The drops are automatically counted and the test is stopped when the current between the electrodes exceeds a given value. The current limiting resistance is ganged with the voltage control to avoid accidental overload, and an electronic delay circuit prevents premature shut-down by transient current surges. Separate indication is given of failure by surface tracking or by puncture of the material. Adequate interlocks are provided to ensure safety in operation.

The equipment is self contained in a compact bench-mounting cabinet, and is simple to use. Once a test has been initiated, it can be left unattended until completion, and may then be quickly reset for a further test.

Circle **28** *for further details.*

Automatic tracking comparator

MS7 Mass Spectrometer

THE MS7 mass spectrometer has been designed specifically for the purpose of measuring minute impurities in solid substances using the spark ionisation technique. It will be of use in fields of science and engineering where it is essential to use materials of the highest purity, such as nuclear engineering, semi-conductor research and manufacture, and in the development of non-ferrous metals and alloys.

Some of the materials which have been successfully analysed down to 0·01 p.p.m. with the prototype model include uranium, reactor grade graphite, germanium, selenium, silicon, gallium-arsenide, magnesium, titanium, tungsten, iron, copper, aluminium, tin and nickel-chromium alloys.

The type MS7 mass spectrometer is a double focusing instrument of the Mattauch type, in which positive ions, representative of the sample composition, are produced when a high-voltage spark occurs between two electrodes of the sample material placed close together in vacuum.

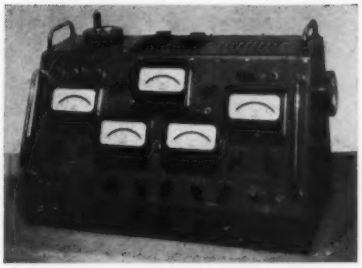
For the analysis of impurities in solids the photographic plate is used as an integrating device, and a series of exposures of gradually increasing length are taken (a rack mechanism allows up to 10 exposures to be recorded on the same plate and the exposure is accurately determined by the total integrated charge falling on the monitor collector). The concentration of the impurity is estimated from the intensity of the lines on the longer exposures, and with this technique concentrations down to the level of 0·01 p.p.m. can be estimated.

The method is particularly useful for giving a general picture of the impurities in a solid. The whole mass range from 7-240, covering all elements, can be recorded in a single exposure of the photographic plate. Compared with emission spectroscopy the spectra are simpler and the elements easier to identify. Moreover, qualitative and semi-quantitative analyses can be carried out without extensive calibration.

Circle **29** *for further details.*

Valve Analyser and Bridge

VALVE analyser Type U-61B is designed for the analysis of valves under any operating conditions, rather than for simple checking using conventional equipment. In addition to obtaining detailed characteristics of all receiving type valves and low power transmitting types, neon tube regulation curves and thyratron control characteristics may be plotted. Positive grid characteristics may also be obtained. The instrument also includes facilities for the standard checks of filament continuity and insulation, short circuits hot or cold, cathode filament insulation and gas leaks.



Valve analyser and bridge

Five large mirror-scale meters indicate simultaneously and accurately, heater volts, anode volts, screen volts, grid voltage and anode or screen currents. Four separate, adjustable, stabilised voltage sources provide the necessary electrode voltages, all of which are readily available for external use by means of sockets on the front panel. Facilities are provided for the insertion of any desired elements in series or parallel with any of the electrode circuits and adjustable anode loads and parasitic stoppers are incorporated.

A comprehensive protection system provides overload cut-outs both in the d.c. supply and mains circuits.

The valve bridge Type 661 which can be used independently or in conjunction with the U-61B is intended for the measurement of the dynamic as opposed to the static characteristics of the valve under test. A wide range of amplification factor, internal resistance and slope measurements can rapidly be made for any valves of static operating voltages and conditions.

Circle **30** *for further details.*

Counters

A NEW type of multi circuit batch counter is being marketed by Radiatron in their IVO range.

This counter has 2 or 4 pre-set count positions. The instruments are available to count either shaft rotation, electrical impulses or strokes (oscillatory movements). The counters change over two or four independent electrical contacts when the respective numbers are reached, and the whole cycle is repeated on depressing a zero set lever or turning a detachable key. Electrical reset is also available.

Single pre-determining batch counters are also available and these are made for either electrical release or mechanical release or for giving an audible warning signal only.

The single and the double counters are available up to six digits and the quadruple counters up to three digits. In each case the numbers corresponding to the various circuits are adjusted independently of one another with finger-grip wheels.

A small electrical impulse counter, also

Multi circuit batch counter

an IVO range product, is suitable for use in control panels and for counting up to 20 impulses per second (or more in special execution). The display panel is $2\frac{5}{8} \times 1\frac{1}{2}$ in. and the counter depth $3\frac{1}{4}$ in. The counter is made for both d.c. and a.c. pulses, the minimum pulse length being 25 milliseconds for d.c. and 33 milliseconds for a.c. Average lifetime of the counter is 180 million counts. The counter is available in non-reset type or with an instantaneous resetting knob or with a reset key. A counter with electrical reset is in development, which will count up to 50 p.p.s.

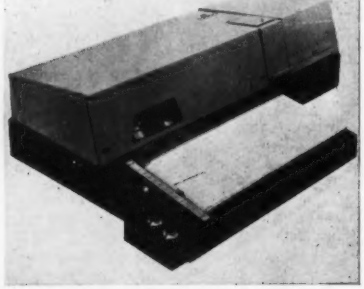
Circle **31** *for further details.*

Beckman Model IR-7 Spectrophotometer

THE Model IR-7 prism-grating infrared recording spectrophotometer has automatic continuous scan from 650 cm^{-1} to 4,000 cm^{-1}. Incorporating a Bausch and Lomb "Certified Precision" 64 × 64 mm grating, the instrument gives a resolution of 0·3 cm^{-1} at 1,000 cm^{-1}, with a frequency accuracy of 2·0 cm^{-1}. It may be used either with double beam or single beam operation, and in the latter case absolute percentage transmittance accuracy is within ±0·2%. Stray radiation is less than 0·1% at the 700 cm^{-1} polystyrene band using NaCl optics. Design has allowed for accurate control of a very wide range of parameters, and presentation is on a horizontal flat chart, which keeps the complete pen trace in view over the whole scan. A large area sample compartment permits accommodation of special sample handling equipment. Special attachments are available for linear absorbance recording, chart ordinate expansion and auxiliary recording. Of particular interest is the built-in repetitive scanning device for study of reaction dynamics. A new patented slit system allows really accurate and reliable programming, and a special Beckman-designed thermocouple detector (with low mass gold-foil element and integral precision lens) produces very rapid response with low noise level.

A complete range of macro and micro cells for sampling gases, liquids and solids is available.

Circle **32** *for further details.*



Beckman model IR-7 spectrophotometer

Continuous-flow Refractometer

THE Hilger continuous-flow refractometer makes a continuous comparison between a reference liquid and a flowing sample. Any change in the concentration of the sample is shown on a meter or recorded. If desired, the instrument can be incorporated in an automatic control system to restore the concentration of the sample to the correct level. The continuous-flow refractometer has many applications in the brewing, chemical, confectionary, sugar, and pharmaceutical industries.

The refractometer uses a null-balance system of measurement; and any change in the refractive index of the sample unbalances the system. A simple servo mechanism restores the balance and indicates the difference between the indices of the sample and reference liquids. The cell containing the two liquids is made from a stainless steel that is approved for use in the food industries. The cell is surrounded by a bath of water, which helps to maintain the cell at a constant temperature. When very high accuracy is required the reference liquid and the water in the bath may both be circulated through an external heat exchanger.

Circle **33** *for further details.*

High Voltage Rectifier A207

SAMPLES of the improved version of the A207 are available immediately. Valves made to this new design are both electrical and mechanical replacements for the older type, but offer the following advantages:

Lower selling price; considerable reduction in size; modified anode structure, with completely redesigned top cap seal, giving greater strength and rigidity; improved filament suspension, reducing the risk of filament fracture; reduced risk of internal flashover.

A brief summary of the valve data is given below:

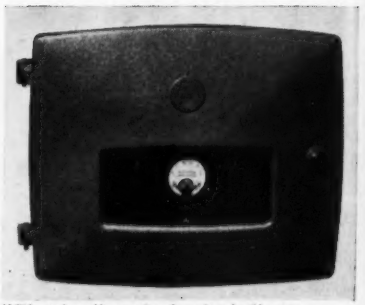
Filament voltage	—	4·0 V
Filament current	—	12·0 V
Peak inverse voltage	—	40·0 kV
Anode dissipation	—	130 W
Peak anode current	—	1·1 A
Mean anode current	—	350 mA
Overall length, nominal	—	8·15 in.
Overall diameter	—	2·34 in.
Base	—	Goliath Edison Screw

Circle **34** *for further details.*

Smoke Density Indicator

THE "ELECTRICON" smoke density indicator Type CSB/6000 is new in design and will be of interest to engineers demanding efficient operation of boiler plants.

Mechanically the "ELECTRICON" type CSB/6000 is extremely robust. Electronically, the instrument is of laboratory quality and can be employed for combustion research or automatic control of combustion.



"Electricon" smoke density indicator

Particular effort has been made to ensure that the instrument can be easily set up and all adjustments can be made from the central control unit, which is under lock and key.

Circle **35** *for further details.*

Miniature Edgewise Meter—Model 220

THE Model 220 has been developed for use in control panels where front space is at a premium.

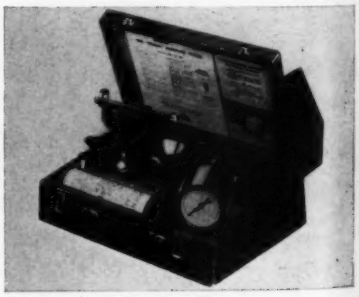
It can be supplied as a voltmeter, milliammeter, and microammeter, commencing from very high microamps. These ranges can also be supplied with rectifier for operation on a.c. supplies. The edgewise meter is available with right hand zero, left hand, displaced, or centre zero pointer position, and is suitable for either horizontal or vertical mounting. The meter occupies a space frontage of 2·5 × 0·62 in.

Circle **36** *for further details.*

Moisture Tester

THE "SPEEDY" moisture tester is self-contained, portable and can be used with accuracy by any unskilled operator. A reading can be obtained on most materials within three minutes. The principle of the patented apparatus is instant release of gas from "SPEEDY" absorbant on contact with the moisture in the sample. The pressure of gas released registers on the dial gauge, indicating the percentage of water.

The "SPEEDY" has been applied to work in foundry, agriculture, ceramics, chemical, concrete, cement, earthwork construction, and textile industries. The complete outfit—comprising the actual testing instrument, a counterpoised balance (no weights needed) scoop for measuring "SPEEDY" absorbent, a tin of absorbent sufficient for 50 tests, a cleaning brush, a spare rubber washer and



"Speedy" moisture tester

complete working instructions—is supplied in a carrying case 15 × 12 × 4¼ in. and weighs 12 lb. Large models are also manufactured to test sample weights of 13, 26 and 43·5 grammes, which are obtained on the counterpoised balance supplied. The overall size, 17½ × 12½ × 6¼ in. with gross weight 16 lb. Different gauges are available to cover all ranges of moisture from zero to 100%.

Circle **37** *for further details.*

Unit Sequencing System

THE unit sequencing system, designed and developed by Gresham Developments Limited, enables any manufacturing process to be sequentially controlled, automatically, from a central position.

The unit implements instructions automatically in accordance with a predetermined programme of operations. It is actuated by means of electrical signals received on completion of each stage of a production process. This may be a predetermined time, temperature, pressure, weight, number of revolutions, power, density, rate of flow, etc. It controls operations such as mixing, heating, cooling, pumping, conveying and, in fact, practically any operation which can be controlled or carried out electrically.

The Gresham unit sequencing system enables a sequencing controller to be built up to meet individual requirements by using the appropriate standard units.

Circle **38** *for further details.*

Humidity Controllers

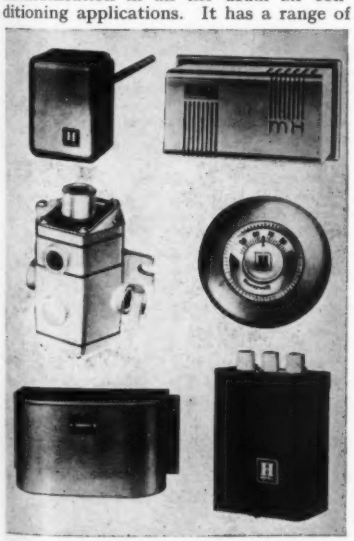
A COMPLETE range of humidity controllers for two position low and line voltage control, and low voltage proportional control has been introduced. Models in the range will control modulating or two-position motors or can be used to control pumps, motors and fans directly. The range is marketed by Honeywell Controls Limited.

The proportional controller is for use with a modulating motor and can be used for control of humidification and dehumidification in all the usual air conditioning applications. It has a range of 20-96% r.h. with a modulating range of 10% r.h.

The range includes several types of two-position controllers, featuring both single and double throw switches. Two types of controller are offered; those using open contact snap acting switches which ensure a differential accuracy of 2% r.h. at mid scale; and those using totally enclosed mercury switches for heavy loads and use in hazardous atmospheres.

The range of controllers features human hair sensing elements which guarantee a high degree of stability.

Circle **39** *for further details.*



Examples of Honeywell's new range of pneumatic controllers

Distance Meter DM100

THIS instrument operates in conjunction with non-contacting probes to provide a basically linear method of measuring distance from 50 micro-inches to half an inch. Distance is read directly from a moving-coil meter, the full-scale range depending on the probe in use. Four probes are available: types A, C, E and F for full-scale ranges of 1, 10, 100 and 500 thousandths of an inch respectively.

Readings are accurate to ±2% of full-scale deflection. The discrimination is better than 0·5 per cent of full-scale deflection.

The length of the probe cable is 10 ft, enabling the instrument to be situated well clear of the test structure. An outlet from the front-panel is provided for connection to recorders or servo-control systems.

The instrument provides a rapid and straightforward means of measuring distance in precision grinding processes and can readily be adapted for such applications as the dynamic balancing of helicopter blades and the measurement of verticality of control rods in nuclear power stations.

Direct indication of expansion is obtained without imposing any load on the item under observation and changes in dimensions can be continuously monitored or recorded against time or temperature.

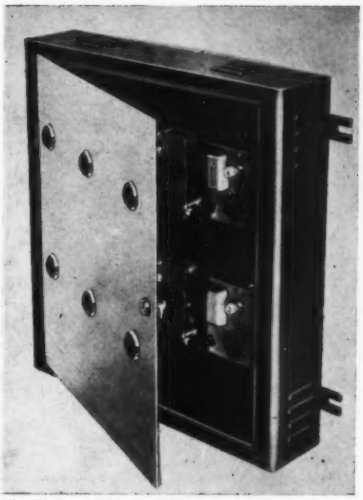
The design is centred on a high-gain amplifier with a negative-feedback loop completed by the capacitance between the probe and test structure. The amplifier input is a reference current derived from an internal oscillator. The output from the amplifier is applied to a feedback voltmeter circuit, and the meter reading is directly proportional to the probe/structure separation.

Circle **40** *for further details.*

Centralised Level Control

A DEVELOPMENT of the Tektor Minor level controller enables up to 150 feet of coaxial cable to be used between probe and unit. Multiple construction of electronic units enables centralised or grouped indication of level.

A single Tektor consists of a probe connected to an electronic unit, the probe being installed on the container. The increase in interconnecting cable length means that the unit may be conveniently situated at ground level for ease of access or maintenance. If centralised level control is required this extension of cable length enables all electronic units to be brought together from different parts of the plant and housed in one case. The interconnecting coaxial cable is supplied with the instrument and no other cables are required from probe to unit. With the Fielden capacitance system of level control there are no electronics on the container.



Six Tektor Minor units built into one case for centralised indication of level

Circle **41** *for further details.*

Watts Photoelectric Autocollimator

A PHOTOELECTRIC autocollimator increases the reliability and speed of measuring angular displacements from which straightness, flatness, alignment, angular rotation and small linear displacements can be determined.

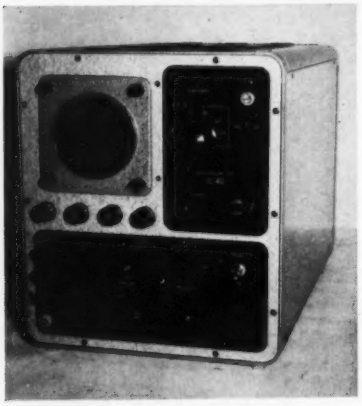
The need for visual observation through an eyepiece is eliminated and operator fatigue leading to possible errors in reading is avoided. The instrument is so sensitive that it is unnecessary to make more than one setting for an accuracy of 0·05 of a second. Although it can be used in the normal visual way when required, the photoelectric autocollimator has particular application where the eyepiece or the micrometer drum is awkwardly placed or inaccessible during use.

The micrometer eyepiece embodies a photoelectric detector consisting of a vibrating slit and a Hilger Schwarz photocell. A centre-zero indicating meter, incorporated in a separate unit which also contains the associated electronic equipment, can be located at a point remote from the autocollimator.

The instrument is first set-up visually and the vibrating slit is then positioned, by rotation of the micrometer drum, so that it oscillates symmetrically about the reflected image of the target wire. In this position the meter indicates zero. Subsequent left or right displacement of the image of the target wire is indicated by a corresponding deflection on the meter. This displacement can be read direct from the meter scale, but for precise accuracy the meter is reset to zero by the micrometer and the displacement is read on the micrometer drum.

The instrument is mains operated. Sensitivity and damping controls, and an "on/off" switch are located in the remote unit.

Circle **42** *for further details.*



Oscilloscope

Oscilloscope

THE Furzehill O.140 oscilloscope embodies a time base which can be used in either triggered or free running condition over a range of 0·1 μsec/cm to 0·5 sec/cm. Fine control of the triggering enables the horizontal sweep to be started at any desired point on the waveform under examination.

The deflection amplifier is direct-coupled and is provided with eight calibrated sensitivities, namely 50, 15, 5, 1·5, 0·5 and 0·15 volts/cm level to 10 Mc/s plus two further sensitivities of 50 mV/cm to 3·3 Mc/s and 15 mV/cm to 1 Mc/s. Because the instrument is intended for pulse examination, the amplifiers are critically damped to obviate ringing.

The calibration accuracy on both time and voltage is better than 5% but an internal calibrating wave of 1% accuracy enables a check to be made at any time.

A 4 in. p.d.a. flat-ended tube is used with astigmatism control, while the graticule is provided with variable illumination which facilitates rapid and accurate measurement.

Circle **43** *for further details.*

"Minidekkor" Autocollimator

THE Hilger & Watts range of autocollimators has been extended by the introduction of the "MINIDEKKOR", a small lightweight instrument designed for the workshop and toolroom. Applications of the "MINIDEKKOR" include the checking of micrometer faces, set squares, vee blocks, small castings and tapers. It can also be used for checking and location of moving slides and spindles.

Angular displacements in two directions are measured simultaneously, by comparison with a standard such as a polygon or angle gauge. The reading is obtained by observing in the eyepiece the position of a reflected cross-line target in relation to a fixed scale graduated in minutes. Readings can be taken direct to 1 minute of arc and estimated easily to 30 seconds.

The recommended maximum working distance is 12 feet. Maximum measuring range is 60 × 60 minutes of arc. Overall length of the instrument is 6 inches and the diameter of the telescope tube is 1 inch.

The eyepiece can be at the end or at the side of the tube. If it is at the side, the scale figures are reversed (because the light is turned through a right angle), but a special graticule can be supplied to overcome this inconvenience.

A mounting bracket can be supplied for fixing the "MINIDEKKOR" to the stand of a universal microscope.

Circle **44** *for further details.*

Automatic Weighing

THIS recently developed automatic weighing control equipment is intended for heavy industrial use; typical applications include maximum weight control on mineral hoists, where the loaded skip weight is checked; control of sand in batching hoppers in foundry work; checking of weight of beer in storage tanks, and control of load on lengths of conveyor.

This equipment involves the use of one, two or three load cells on which the load is supported. The load may alternatively be suspended from up to three suspension type load cells.

The load cells are connected to a remote relay unit which integrates the output from the cells. The integrated output current is monitored and when it reaches a value corresponding to the selected operating weight, the relay in the control unit is operated and actuates the control mechanism, e.g., conveyor motor, chute gate, automatic valve, diversion flap, etc.

The load cells are of standard construction. The relay unit consists of a withdrawable chassis housed in a cast weatherproof case suitable for outdoor mounting, or in a sheet steel case with hinged lid for indoor use.

It can also be supplied in a flameproof version, Buxton certified and intrinsically safe.

The equipment is suitable for the range of weights normally covered by standard load cells, from 50 lb up to a thousand tons or more, and is provided with operating adjustment over any desired range of weights. It gives repetitive accuracy of better than 1%.

Price of a typical unit for weights up to 2,000 lb, employing one load cell, the relay unit being housed in a standard sheet steel case, is £120. Units for greater weights and in heavier housings cost rather more.

Individual requirements will be quoted for on receipt of details.

Circle **45** *for further details.*

Miniature Tropical Paper Condensers

REQUIREMENTS of certain circuitry are such that low inductance and good impedance characteristics are essentials, making the paper dielectric condenser the obvious choice. Unfortunately, while other components have been reduced in size, this type of condenser has remained constant due mostly to the minimum thickness of dielectric available being of an unnecessarily high voltage rating.

New materials have now made it possible to produce condensers still having two layers of paper dielectric to each solid foil electrode, reduced in physical size to that of metallised paper condensers with comparable voltage rating.

These condensers employ a method of sealing the element into an aluminium tube with neoprene bungs and use "Visconol-X" impregnating compound. They are of similar construction to the "Metalmite" range for which Ministry Type Approval for Specification R.C.S.131, Cat. 40/70 H2 has been granted.

Insulating sleeving can be fitted at slight extra cost.

The working voltage is 150 V, d.c., tolerance of capacity ±20% and the temperature range of operation —40 to +70°C.

Circle **46** *for further details.*

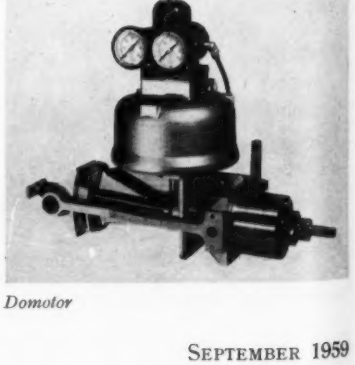
"Wee Willie" Control Valve Model 5060

MANY challenging engineering problems are encountered in the design of a control valve for 50,000 p.s.i. working pressure. Severe forces may cause stretching, distortion and friction which must be eliminated or reduced to an absolute minimum throughout the operating assembly. The "WEE WILLIE" Audco Annin control valve has been developed to provide the research and development engineer with a control valve capable of completing an automatic circuit involving extremely small flow rates at exceptionally high operating pressures.

The linkage arrangement provides an adjustable infinite valve plug stroke selection (Cv) from a minimum of 0·010 to a maximum of 0·150 in., and converts the Domotor operating force to 12,000 pounds at the shortest setting and 2,000 pounds at the longest.

Distortion in the valve body proper is substantially reduced by connecting the inlet pressure directly into the valve seat ring and the box-like frame arrangement carries the actuating loads without stretch or distortion. The main operating arm is carried on needle bearings and the connecting operating rod has hardened ball ends operating in hardened steel sockets. All operating parts are held in constant tension by spring loading the stem driving cross head. This eliminates all lost motion. An Audco Annin-developed unique packing assembly includes a combination Teflon 'O' ring closely confined and operating over hard superfinished valve stem. Positive sealing is obtained at 30,000 p.s.i. with a minimum friction factor.

Pilot plant operation often involves flow ranges comparable to contemplated plant operation. The "WEE WILLIE" pilot plant valve has a water Cv range of from 0·0000001 to 0·1. The conventional open orifice valve seat and plug is not generally applicable to high pressure drop and flow rate, due to resultant high velocity, small



Domotor

area, lack of strength and limited rangeability. Each Audco Annin Flo-Mike valve seat is conservatively rated at a Cv rangeability of a 1,000 to 1 and by substitution of 1 or 2 Flo-Mike seat units a valve rangeability of 100,000 to 1 or 1,000,000 to 1 is obtained. By changing the stroke range to correspond with the desired maximum Cv, the same degree of plug positioning accuracy is obtained to assure precise flow control. A conventional orifice and plug can be quickly installed for 'on-off' or semi-throttling services should such construction become desirable. In application in an experimental project (comparable to plant processes using control valves ranging in size from $\frac{1}{8}$ in. to 10 in.) the experiments can be carried through to completion with "WEE WILLIE" without change of the Flo-Mike seat unit.

Circle **47** *for further details.*

Transistor Servo Amplifier TA.I.G

THIS amplifier is designed to provide the control phase power for the Pullin size 10 servomotor (Type R124-G) or the Pullin high performance size 10 motor generator (Type R807G). It is also capable of driving a suitably wound size 15 motor or, through a centre tapped transformer, any other suitable load.

The nominal output power is 4 watts at an ambient temperature of 55°C but up to 6 watts can be obtained below 50°C. Although the amplifier is primarily intended for operation on a balanced 400 c/s supply of 26 volts it may also be powered with 18 volts d.c., when it will accept signals in the frequency range of 150 c/s to 3 kc/s.

The basic input resistance of the amplifier is 3·5 kohms in series with a coupling capacitor of 1·6 μF (between terminals E and 6 or 7). When the amplifier is operated in a feedback system terminals 6 and 7 (which are connected together internally) may be used as a "summing point" for several signals. For this purpose a "built-in" resistance of 22 kohms is provided between terminal 3 and terminals 6 and 7. Other summing resistors may be added externally between terminals 1 and 6 and terminals 2 and 7.

The mechanical design of the amplifier has been evolved to meet the requirements of Service specifications for resistance to environmental extremes. Most of the components are mounted on a printed circuit card attached to four square corner pillars which are integral with a cast aluminium base-plate. The whole assembly is moulded into a block of silica-loaded resin with the base-plate forming one face of the block and the pillars the corners. Heat removal is effected by conduction from the output transistors to the base-plate, and the effective cooling area may be increased by mounting the amplifier on a metal plate or chassis.

Circle **48** *for further details.*

Transistorised Dual Stabilised D.C. Supply Type P.P.3

THE P.P.3 comprises two transistorised 0 to 30 volts 1 amp stabilised d.c. power supplies in one case operating off a common mains transformer. The two sections are floating and can be operated separately, connected in series to give a maximum

Dual stabilised d.c. supply

output of 60 volts at 1 amp or to provide positive and negative voltage supplies simultaneously (maximum 30 V each).

Each section covers the range from 0 to 30 volts in three overlapping 10 volt ranges with the variable control directly calibrated in volts. In addition to this a voltmeter and ammeter are provided which can be independently switched to either section, the ammeter having two ranges.

Four terminal output networks are provided to enable the resistance of the connecting leads to the load to be virtually eliminated.

Overload protection is effected by a circuit which gives completed protection against both progressive and sudden (short circuit) overloads. This circuit can be reset from the front panel by operation of the ON-OFF switch. Protection against internal failure or excessive mains surges is handled by a panel mounted fuse in the mains circuit.

The unit is intended for operation on both 100-120 volts and 200-240 volts mains, the voltage selector being located at the rear of the case.

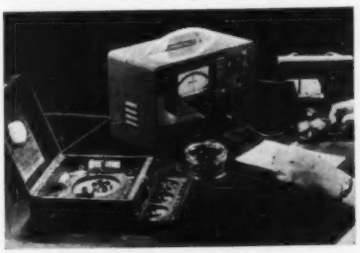
Circle **49** *for further details.*

"Smoothrator"

THE "SMOOTHRATOR" not only tests the surface finish of raceways and balls, but also detects major causes of bearing malfunction, such as dirt, other contamination or damage.

Although the "SMOOTHRATOR" has not been designed as a torque tester it nevertheless can produce tests results which indicate the usefulness of bearings for exacting gyro gimbal, synchro and other low torque applications. In applications requiring low noise or vibration levels, "SMOOTHRATOR" test results are objective, reliable guides to bearing performances in completed assemblies.

Results are read directly in units related to limits established by the bearing user and are not effected by differences in the operator's technique, skill or judgment. A test time is 30 to 50 seconds, giving an average yield of 60 to 100 bearings per hour.



"Smoothrator"

Easily portable, the unit can be set up in 10-15 minutes including calibration. The only requirements being a power source of 230-250 volts, 50 cycles (a voltage regulator may be needed if the voltage fluctuates beyond this range) and fluorescent lighting to provide the stroboscopic effect that indicates bearing speed.

Price of the "SMOOTHRATOR" is £214 13s. 0d. and delivery from stock.

Circle **50** *for further details.*

Control Relay

THIS equipment comprises a transistor relay, associated indicator lamps and power supplies for the remote switching (and indication) of loads where the power through the control-circuit contacts must be kept to a minimum.

The control-circuit power is limited to less than 5 milliwatts and under many conditions will be less than one milliwatt. Maximum switching capacity of the unit is 15 amp at 250 volts a.c. (non-inductive).

The sensitive control relay fitted with a switch, to control the load current, and light-duty contacts, to switch the low-voltage indicator lamps, is connected in series with a transistor across a low-voltage d.c. supply derived from a transformer and rectifier. A bias applied to the transistor causes the relay to energise and close the normally-open contacts of the changeover switch. In order that the relay shall fail to safe the normal operating condition is that in which the relay is energised; the opening or closing of the control contacts (depending on mode of control) removes the bias from the transistor causing the relay to de-energise and open the normally-open contacts.

This control relay provides its own control current and cannot be operated by external signals. It has application wherever minimum arcing at the control contacts is required.

Circle **51** *for further details.*

"Vinkors" Pot Cores

"VINKORS", which are made from a new high-stability, low-loss grade of Ferroxcube, allow the inductance of coils wound on them to be pre-calculated to an accuracy of ±3%.

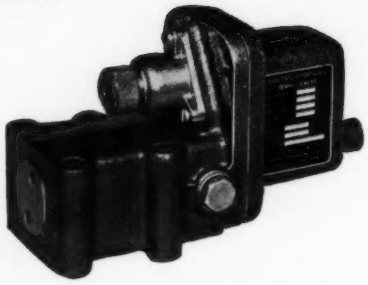
A variable magnetic shunt is built into the core by means of which the inductance of the assembled coil can be adjusted over a range of ±7% and with an accuracy of better than 0·02%. This provides adequate allowances for the small tolerances on the core itself and also for normal circuit tolerances. The adjuster is readily accessible when the assembly is mounted in position, it is self-locking, and designed for easy adjustment with a screwdriver.

The present range of "VINKORS" comprises five types for use at frequencies up to 200 kc/s, with outside core diameters of 18, 21, 25, 30 and 35 mm respectively. Each size of core is available with an effective permeability of 160, 100 or 63 as required.

Single- or multi-section coil formers of polystyrene or low water-absorption nylon are available for each size of core.

Circle **52** *for further details.*

Circle 56 for further information



SERVO VALVE

Specially designed for industrial applications. Available for 2.5, 5, 10 and 15 g.p.m. From 7 watt input to 12 h.p. output. Suitable for operation up to 3,000 lb. per sq. in. in temperature range -20°C to + 100°C.

INDUSTRIAL

MICRON FILTER UNIT

For highly efficient filtration of particles greater than 5 microns from industrial hydraulic systems. Available for use integral with the Sperry servo valve or separately as a line filter.

SERVO COMPONENTS

SERVO VALVE DRIVE AMPLIFIER

To provide the link between the signalling elements of the servo loop, e.g., Sperry inductive pick-offs, synchros or tachos and the electro-hydraulic servo valve. Transistorised design, suitable for operation on 50 c.p.s. supply. Power gain 600 mA differential current into a 20 ohm load with 20 mV input, i.e., of the order of 10^8. Designed to comply with industrial conditions.

AND SYSTEMS

For over 40 years SPERRY engineers have been developing high-precision servo systems, for ships, aircraft, naval ordnance and guided missiles. The unrivalled experience gained in advanced servo techniques is being applied to the development of industrial components and systems.

Electric signalling combined with hydraulic actuation has been chosen by SPERRY designers as the most efficient and reliable means, with the widest adaptability to specific applications. Three out of a number of precision components are described here. Please write for details of the comprehensive SPERRY range of electro-hydraulic controls now placed at the service of control engineers, for a wide diversity of industries.

SPERRY **a world-famous name in precision controls**

SPERRY GYROSCOPE COMPANY LIMITED (INDUSTRIAL DIVISION)

Great West Road, Brentford, Middlesex. Telephone: ISLeworth 1241. Telex: 23800

NEWS OF THE INDUSTRY

Robotug Installations

FIRST E.M.I. Robotug driverless trolley system (*Instrument Practice*, June, 1959, pp. 615-618) went into operation recently at the Newton Abbot goods yard of the Western Region of British Railways. The Robotugs are being used to convey goods discharged from railway wagons to selected sites for loading into motor vehicles for outward delivery.

The basic electronic system operates by making a trolley follow a single wire, which at Newton Abbot is laid just below the platform, through which an alternating current of a specified frequency is passed.

The Western Region of British Railways have had for some years now practical experience of flat conveyor and power truck operation on their goods sheds, and it is considered that the driverless-truck scheme will embrace the merits of both methods and produce greater efficiency and economy.

One of the largest suppliers of engineering small parts in this country has ordered a Robotug system employing 40 driverless trucks.

This company plans to reorganise completely its main factory stores in the Midlands. The new procedure will revolve around the use of these Robotugs. Quantities of the various parts will be check weighed into boxes, passed along conveyor belts and loaded into the driverless trolleys for transportation to other sections of the building.

Ferranti Electricity Meters now Produced in Scotland

To meet the increased demand for electricity meters in Scotland, Ferranti Limited announce that production of meters has recently commenced in their Dundee factory.

This policy decision is analogous to that taken by the company early in 1957 to manufacture distribution transformers in Inverness in order to satisfy the requirements of the Scottish market, in particular the North of Scotland Hydro-Electric Board. This latest development at Dundee is designed to speed delivery of meters and provide increased service facilities.

Initially, production of the company's single-phase FMm and polyphase FMx meters is being undertaken, but it is anticipated that as the demand increases, other developments of the FM meter range will also be produced. The Dundee factory has already produced meters for both home and Commonwealth markets.

B.S.A. Tools Division

IN order to facilitate administration, and to increase efficiency, the small tool and broach manufacturing activities originally carried out by B.S.A. Tools Ltd. have been transferred to two new companies, namely:

B.S.A. Small Tools Limited,
Montgomery Street,
Sparkbrook, Birmingham, 11.
Telephone: VICtoria 2351.

B.S.A. Broach Co. Limited,
Studley Road,
Redditch, Worcs.
Telephone: Redditch 1291.

These two companies, together with B.S.A. Tools Ltd., which will continue to carry on its machine tool manufacturing activities at Mackadown Lane, Kitts Green, Birmingham, 33, *Telephone* STEchford 3071, will operate as separate and wholly owned subsidiaries of the Birmingham Small Arms Co. Limited. Management will be carried on by the same executive and personnel as hitherto.

Home and export sales arrangements will remain the same.

The purchase of materials, etc., for each of the three companies will temporarily be in the hands of B.S.A. Tools Ltd., as purchasing agents. Suppliers need not at present open separate accounts for B.S.A. Small Tools Limited, and B.S.A. Broach Company Limited. Delivery instructions will be clearly indicated on all purchase orders.

£250 Award for Doubling Card Sorter Speeds

A SIMPLE idea for increasing the operating speed of I.C.T. 80-column punched card sorters, with a negligible increase in cost, has won £250 for Mr. Richard Bowker, senior field engineer at the I.C.T. Field Engineering Headquarters, Luton.

Automatic card-sorting machines incorporating this innovation have been successfully tried out in the field, and it will be used in a new I.C.T. sorter. The innovation can also be adapted in various ways to existing designs, permitting easier adjustment and reduced maintenance time. Another promising application is in card sorting for computer techniques.

B. & R. Relays Ltd. Technical Sales

B. & R. RELAYS have strengthened their specialised Technical Sales Force, which is now independent of any other selling organisation. The sales offices, situated at Temple Fields, Harlow, Essex, are under the care of Mr. H. J. Beach, sales manager, with adequate area representation distributed throughout Great Britain.

Precision Alignment in Nuclear Reactors

IN the construction of the nuclear reactor, provision must be made for precise placement of the uranium (or other fissile material) fuel rods and graphite moderators. Upon this precision depends the safe and efficient working of the reactor.

It is achieved by locating a series of guide-holes in the reactor-chamber roof with a corresponding system of orifices in the chamber floor. By aligning to very close tolerance both sets of holes, fuel and moderating rods can be placed—throughout their length—in the mathematically correct positions.

The Taylor-Hobson "Micro" alignment telescope is used for the precision correlation of upper and lower systems, between which there is a vertical distance extending in some cases to one hundred feet. The "Micro" alignment telescope locates each hole to the very close tolerances laid down for each stage of construction, correctly channelling fuel and moderating rods, and ensuring the overall accuracy specified by the Central Electricity Authority.

Savelite Automatic Control

RADIOVISOR PARENT LIMITED have now received their Medal and Diplome D'Honneur awarded by the Municipal Council of Paris for their exhibit under the Scientific Section at the Floralies Internationales held in Paris in April, 1959.

The exhibit consisted of a Savelite automatic lighting control fitted in "The Greenhouse of the Future" to provide, automatically, supplementary artificial light whenever natural light decreased below a pre-set level.

Rank Xeronic High Speed Printer

FERRANTI LTD. have ordered the first Rank Xeronic printer—the 3,000-line-a-minute output printer for use with electronic computers.

This machine, which is built by the Electronics Dept. of Rank Precision Industries, will be delivered to Ferranti in November, 1960. This machine will be used with one of the Ferranti computing systems.

It will print up to 5,000 characters a second and will simultaneously print its own forms to contain the information. The printing spread of 24 in. allows two copies of 12 in. width or four copies of 6 in. width of the print-out to be supplied side by side. The paper output speed is 40 feet a minute.

Besides its extremely high speed, the form printing is one of the main features of the Xeronic. The model for Ferranti

will print four different forms, the correct form being selected electronically by signals from the computer.

E.M.I. Demonstration Unit Begins Tour

THIS month a new demonstration unit, to show the advances being made in electronic machine tool control systems, leaves for Paris. Later main industrial centres in Belgium, Holland, Germany, Switzerland and Italy will be visited.

The trailer has been fitted out as a complete modern workshop. There is a programmer's office where punched tape is prepared to produce any type of workpiece—from a simple two dimensional template to a three dimensional die.

Dominating the workshop area is a large Kearney & Trecker milling machine of an entirely new type, which is capable of carrying out the most complex operations controlled entirely from punched tape.

Among other industrial aids that the unit will demonstrate to European industrialists is the latest type of closed circuit television, now being used by an ever-increasing number of organisations to give management finger tip control.

E.M.I.'s machine tool control systems, which enable profiling and die sinking to be carried out direct from blueprint to finished part by punched tape without the use of a computer, can now be fitted to machine tools manufactured by the world's leading companies. It provides one, two or three dimensional control for any machine, operated either hydraulically or manually. Simple programming enables master cams, templates, models or finished parts to be produced easily.

Future plans for the unit include tours behind the "Iron Curtain". Russian experts have already expressed great interest in the E.M.I. system.

Repair and Overhaul Facilities at Smiths Cheltenham Factory

A NEW and very comprehensive workshop for the repair and overhaul of aircraft instruments has recently been opened by Smiths at their Bishops Cleeve factory in Cheltenham to co-ordinate these essential services at the source of manufacture.

The repair organisation, although based at Cheltenham, is in fact the headquarters of the Group's repair activities, and whilst instruments manufactured by other members of the Group are subcontracted to the member factories, the administration and recording of all the various transactions are handled at Cheltenham.

General view of Smiths' new workshop

Since its inception in February of this year the new workshop receives on an average 1,000 instruments per week, of which between 400 and 500 are repaired on site, and the remainder subcontracted to member companies.

Whilst facilities for complete overhaul, test and inspection are available to cover both general instrumentation and more complex systems, the full resources of the Cheltenham production organisation also give every available support to the repair organisation, particularly in times of exceptional peak demands.

A feature of the organisation is the provision of special courses of instruction in the overhaul of Smiths Group instruments. Pupils are trained by aviation training unit instructors, using identical equipment to that used by the operators.

The work benches are specially designed to accommodate ten operators and are supplied with grouped essential services to ensure complete adaptability for the overhaul of all types of flight instrument. Only standard measuring equipment is used in the workshop and this equipment is duplicated in the inspection room, which adjoins the main workshop area.

Instruments are classed as "factory rebuilt" and are re-issued with their full warranty and incorporate all current essential modifications.

The quality control department is a separate unbiased unit where causes of failure are analysed, recorded and made available to the engineering department and research and development departments for operational investigations.

The British Thomson-Houston Co. Ltd. Order First "Space 30" Computers

THE first two production models of the Solartron Electronic Group's new "Space 30" analogue computer have been ordered by the British Thomson-Houston Co. Ltd., of Rugby.

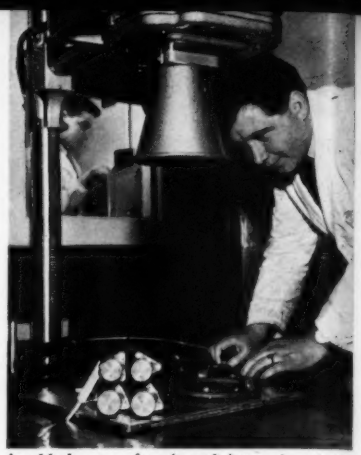
The computers will be used in the analysis of complex control problems encountered in the application of BTH electric motors and controls to a wide range of industrial requirements, at home and abroad. Such requirements include pit-head winding machinery, printing presses, textile and paper manufacturing.

Texas Instruments Expansion Programme

WORK started at the end of August on the new plant for Texas Instruments Ltd. which is being built at Mantons Lane, Bedford. The new building will have a manufacturing area in the form of a hollow square of 100,000 square feet, and it will be air conditioned throughout.

Safe Wiring for Jets

A PORTABLE industrial X-ray unit, supplied by Marconi Instruments Ltd., is being used for the inspection of the electrical wiring of aircraft jet engines. The wiring is covered by Neoprene, or synthetic rubber mouldings, to form a single unit, commonly termed a cable harness. Any strain, kink or displacement of wires can be detected on the X-ray plate and the necessary action taken, thus ensuring complete reliability in the product. Terminations on certain types of plugs and sockets used in vital aircraft circuits are also tested.



A cable harness for aircraft jet engines being positioned for radiographic examination with a Marconi 90 kVp portable X-ray apparatus. Through the lead-glass protective window can be seen the X-ray control unit

Agreements

AN agreement has been concluded between **A. Gallenkamp** and **J. W. Towers** whereby Gallenkamp will acquire the business of Towers. Towers will continue to trade as a separate company and Mr. J. S. Towers has agreed to hold office as managing director for a period necessary to ensure smooth co-ordination of interests.

Rocol Ltd. and the **Société Nouvelle des Huiles Minerales** of France have signed an agreement for the manufacture of Rocol molybdenised and other specialised industrial and motoring lubricants in France and for their distribution throughout the European Common Market area.

Alfred Bullows and the **Gray Co. Inc.** of Minneapolis have made an agreement whereby Bullows have sole distribution rights in the U.K. for the complete range of Graco industrial equipment.

Society of Environmental Engineers

A SOCIETY of Environmental Engineers has been formed to provide a forum, by meetings, publications and visits, for the exchange of information and views among those engineers who are concerned with the development of equipment to withstand shock, vibration and other forms of environmental conditions, and who research in these fields.

The first meeting was held in London on the 29th May, 1959. Some fifty members and guests attended and papers reviewing the field of work were presented by Mr. D. A. Nutt (Armstrong Whitworth Aircraft Ltd.), Mr. F. I. L. Knowles (Ministry of Supply) and Dr. P. Grootenhuis (Imperial College).

A future provisional programme has already been decided upon, and includes these meetings:

On 23rd September, 1959, at 6 p.m. at the House of the Royal Society of Arts, two papers were given: "Electrical characteristics of moving coil vibrations" and "Some electronic measurements of environmental parameters."

On 25th November, 1959, at 6 p.m. at the Imperial College the paper will be:

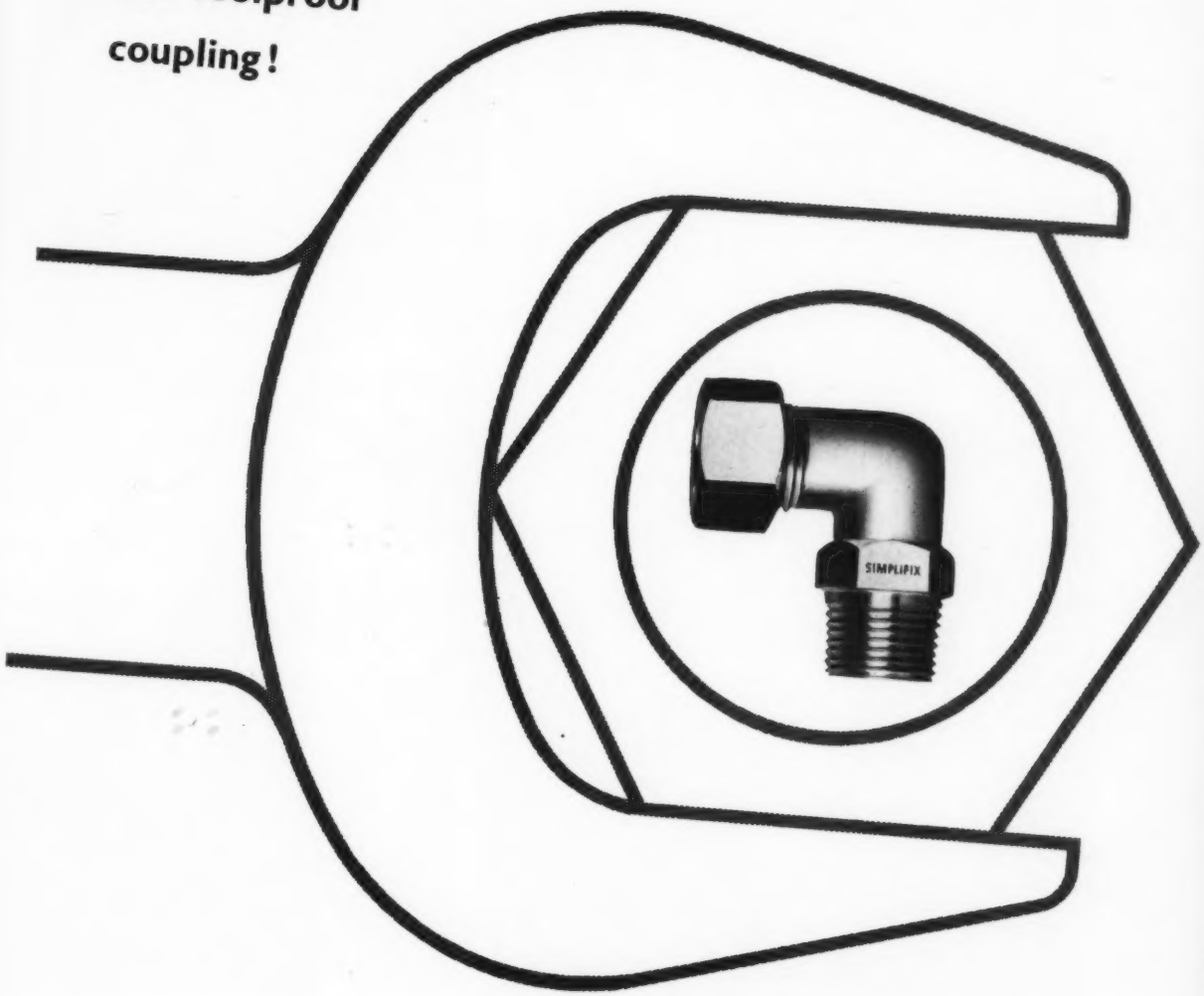
Circle 57 for further information

So simple!

So surely SIMPLIFIX

the foolproof

coupling!



Simplifix couplings form a perfect joint on almost any kind of tubing including those with very thin walls. All that is required is tightening with a spanner— no special work is required on the tube and the anti-friction washer prevents the tube twisting when the nut is tightened. Simplifix couplings are suitable for all pipe line systems up to 2" o.d. In a wide range of interchangeable standard fittings. Non-standard fittings of all kinds can also be made to order. Write for further information and fully illustrated catalogue.

SIMPLIFIX

SIMPLIFIX COUPLINGS LTD . HARGRAVE RD . MAIDENHEAD . BERKS . TEL: MAIDENHEAD 5100

A member of the ALENCO Group of Companies

"The investigation of jet induced vibration in aircraft."

Early in the new year, on 17th February, 1960, at 6 p.m. at the Imperial College, a further two papers will be given: "Calibration of accelerometers" and "A review on the setting up of a heavy vibration laboratory".

It is intended that the first Annual General Meeting of the Society will be held on 30th March, 1960, at 2-30 p.m. at the House of the Royal Society of Arts.

Discussion meetings and visits in London and elsewhere are expected to take place on intervening dates. This Society has already circulated to its members, papers from similar societies in the United States of America.

Membership and associate membership is open to scientists and engineers working on these subjects. Sponsor membership is open to firms similarly concerned. Details may be obtained from the Secretary, The Society of Environmental Engineers, 42 Manchester Street, London, W.1.

Ferranti Edinburgh Laboratory Extension

On 2nd September, Mr. Aubrey Jones, M.P., the Minister of Supply, opened a new £150,000 extension to Ferranti's existing laboratory at Crewe Toll, Edinburgh. This will be used for the production of a new series of high-precision gyroscopes and accelerometers for inertial navigation systems used in aircraft, missiles and other vehicles.

The manufacture of instruments for inertial navigation presents just as many problems as the basic design, and indeed, in much of the work the two problems are inseparable. It is imperative that no dust particles greater than about 0·5 micron in size, or excess moisture, are present in the area where assembly of these instruments takes place. For this reason the assembly and inspection areas and the store room for finished parts are temperature, humidity and dust controlled by means of special plant.

Special precautions will be taken to ensure that machined components do not carry any particles of dust, etc., from the machine shop into the clean areas. This will be achieved by a system of double air locks between the machine shops and a special cleaning room which is equipped with ultrasonic cleaners. A second double air lock between the clean room and the air conditioned store room ensures the minimum transfer of air and hence dust, between the conditioned and non-conditioned areas.

Strict precautions will also be taken to ensure that dust particles, hair, etc., are not carried into the clean areas by the operatives.

Initially, work will be concentrated on the development and manufacture of components only, but later on it is expected that the scope will be extended to include the development and building of inertial navigation systems. Much of the present work is concerned with the manufacture and further development of a single axis floated rate integrating gyro, manufactured under licence from the Kearfott Company, U.S.A., and a pendulous integrating gyro accelerometer, the development and manufacture of which has been undertaken completely at Edinburgh. It is also expected that future development work will cover smaller gyros of roughly equivalent performance to the present design.

The design of all instruments produced at Edinburgh is based on the fluid supported system evolved in the U.S.A., and which is now generally accepted as having random errors very much smaller than the more conventional gyros in which friction of the gymbal bearings has been the main trouble in achieving high performance.

Changes of Address

English Electric Co., Bristol Office: Equity and Law Building, 36/38 Baldwin Street, Bristol, 1.

British Insulated Callender's Cables Ltd., Northampton Depot: 18/22 St. George's Street, Northampton.

Lancashire Dynamo Group, Newcastle Office: Eagle Star House, 32-34 Moseley Street, Newcastle-upon-Tyne, 1.

Conferences

A **Control Systems Components Conference** will be held on 5th and 6th November in Dallas, Texas. The conference will be a joint effort with the I.R.E., A.I.E.E., S.A.E., I.S.A., and A.S.M.E. The programme will include sessions on magnetic components, instrumentation, hydraulic components and electromechanical components.

The **Third International Conference on Medical Electronics** will be held in July, 1960, in association with the International Federation for Medical Electronics.

The Harrow and Wembley Productivity Association, in conjunction with the British Productivity Council are holding a one-day conference on **Planned Maintenance** on 6th October.

Courses

Courses on **Temperature Control** of one day's duration are to be given by West Instrument Ltd. The first courses are to be held on 14th and 15th October at their London office, and instruction will be given on the saturable core reactor. Further information from: Mr. J. Hartnett West Instrument Ltd., 52 Regent Street, Brighton, 1, Sussex.

A three-day course on **"The Six and the Seven"** is being organised jointly by Britain in Europe and the Federal Trust for Education and Research and will be held on 28th to 30th October.

Exhibitions

The 9th **A.S.E.E.** Exhibition will be held in London at Earls Court from 5th to 9th April, 1960. The feature will be "Marine Electronics". Exhibits will include propulsion equipment, water-tight fittings, communications, radar, heating, lighting, generating and all ship electrical equipment.

Elliott Nucleonics held an exhibition recently at which the nuclear power station simulator for the Berkeley Power Station was shown for the first time in public. Health monitoring equipment and transistorised reactor and plant control instruments were also shown.

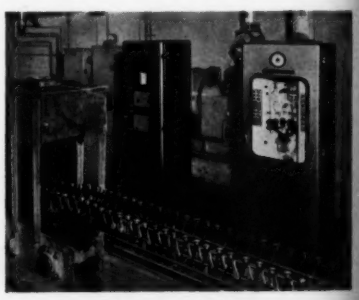
Servomex Controls exhibited a range of electronic equipment at Glasgow recently.

Monitoring Tonic Water

One of the problems in the preparation of tonic water is to maintain precisely the ratio of concentrate to water and to this end Messrs. Schweppes Ltd. have recently installed an E.I.L. titromatic analyser, in their Hendon bottling plant.

This apparatus, designed and made by Electronic Instruments Ltd.,automatically and continuously monitors the final stages of manufacture by taking periodic samples from the production line and titrating these to a pre-set end point. Thus not only is the laboratory staff spared a tedious and time consuming operation, but a continuous graphic record of the tonic water stream is provided and immediate warning is given if changes in concentration occur.

The titromatic analyser is housed in two pedestal cabinets, which are hermetically sealed against humidity or fumes. One cabinet houses the chemical glassware which includes the sampling and titrating unit, while the second cabinet encloses the electronic control and recording equipment. The titromatic analyser is so flexible that it can be adapted to suit almost any plant conditions including titrating to single or double end points and this application is a typical example of its use in the food manufacturing industry.



Model 34 Titromatic Analyser in use at Messrs. Schweppes Limited

Research for Industry, 1958

D.S.I.R. H.M.S.O. 1935 *pp. Price* 7*s.* 6*d.*

This publication first came into being last year when the annual report of the Council for Scientific Research was separated from the section dealing with the Research Association movement. This year's issue contains a review of achievements; two articles on research topics, "The Research Associations: their place in the evolution of scientific endeavour"; and "New ideas, new products, new processes: how co-operative research serves the textile industry", a complete catalogue of the Research Associations, describing the scope of each, and the Industrial Grants Committee's statement of policy for the period 1957 to 1964. The Committee envisage that in the next five years there will be a big expansion of existing Research Associations, and one or two new ones are anticipated. Nearly one-fifth of net output of British manufacturing industry is not covered properly by existing research facilities and some of these trades may in the future be appropriately served by grant-aided bodies.

This is for the record

A new chart roll is being fitted to the Arkon Recorder. The old one has gone for analysis and comparison. Soon the door will be closed and the pen will make its clear current indication.

Arkon Recorders measure gas and air flow, pressure or vacuum, or pressure and vacuum ; flows in one inch pipe or 36 inch mains, pressure or vacuum from 0.1 inches water gauge to 50 lb. per square inch. They give a clear, unmistakable record which you can read like a book, without hesitation and without mistakes. You can leave the chart on for a few hours, a day, or a week—the record will always be there. Easily read, easy to look after, robust enough to stand on the job, Arkon Instruments can help the control of any process—and their accuracy will satisfy even the men in the lab.

More about them in pamphlet AC/110

WALKER, CROSWELLER & CO. LTD., CHELTENHAM

Telephone: CHELTENHAM 56317

EXPORT NEWS

E.M.I. Computer for Australia

THE first order from Australia for an EMIAC II analogue computer was recently received by E.M.I. Electronics Ltd. from the Australian Government Aircraft Factory, Melbourne. The contract is for a two-module computer.

EMIAC II is a general-purpose analogue computer of great versatility which is ideally suited to deal with the varying work pattern handled by the Australian establishment. It is designed to be built-up in module form to meet an expanding requirement.

In the past the Australian Government Aircraft Factory has had to rely on external computer facilities, and the provision of a machine "tailored" to meet its specific requirements will offer great advantages.

Important feature of EMIAC II is its use of interchangeable "C" boxes. These enable a simple simulator, for example, to be tailor-made to meet a specific problem at the price of a mass-produced instrument.

Order from Sweden

A CONTRACT worth about £15,000 for 12 manipulators for the remote handling of radioactive materials has been placed with Savage and Parsons, of Watford, Herts., by Aktiebolaget Atomenergi, Sweden.

200,000 Dollars Order for Marconi Instruments

MARCONI INSTRUMENTS LTD., through its agents in Canada—the Canadian Marconi Company—has received an order from the Canadian Department of Defence Production for 200,000 dollars worth of telecommunication measurement equipment.

In all, nearly two hundred instruments are to be provided, including signal generators, portable frequency meters, oscilloscopes, wave analysers, and transmission test sets. Of particular interest is the bulk order for the White Noise Test Set, Type OA1249A; this equipment permits realistic measurement of intermodulation products and noise in multi-channel link equipments. Also on order is a quantity of the Derivative Test Set, Type OA1259, which is used in testing and aligning radio link modulators and demodulators.

Deliveries of the instruments, which are being manufactured at the St. Albans works of Marconi Instruments, are expected to commence shortly.

Gresham's £20,000 Transformer Export Order for Singapore

AN order for £20,000 of public electricity supply transformers has been received from the Electricity Department of the City Council of Singapore by the Gresham Transformer Group, Twickenham Road, Feltham, Middlesex.

The order consists of twelve 500 kVA and fifteen 300 kVA Gresham transformers.

Plessey "Mine" Type Precipitators for Italy

NUCLEONIC equipment designed and manufactured by Plessey Nucleonics Limited has been ordered by the Nuclear Power Plant Company Limited, the British company engaged upon the construction of an atomic power station at Latina in Italy.

The equipment consists of nine Mk. II pneumatically actuated "mine" type precipitators for the detection of burst fuel elements. Plessey Nucleonics has designed and developed this equipment applying the results of operational experience gained from similar Plessey equipment installed at Britain's Calder Hall power station.

Basically, the equipment operates in the following manner. Coolant gas from each of the fuel channels in the reactor is sampled periodically by the precipitator. Should a burst in the fuel element can occur, fission products will escape and contaminate the coolant system. Two of these fission products, krypton and xenon, are gaseous and subsequently decay into active solid products which may be collected by means of electrostatic precipitation on a wire collecting surface. The wire is then passed through a scintillation counter working in conjunction with a ratemeter which indicates the level of activity on the wire.

£100,000 Order for Marconi Marine

THE MARCONI INTERNATIONAL MARINE COMMUNICATION CO. LTD announces the successful conclusion of negotiations with the Polish organisation CENTROMOR (Central Import and Export Office for Ships and Marine Equipment) as a result of which Marconi Marine have received an order for over £100,000 worth of marine radio equipment.

Under this order transmitters, receivers, direction-finders, echometers and other equipment will be supplied to provide complete radio installations for 24 ships to be built in Polish shipyards for delivery to Indonesian owners.

Solartron Radar Simulation System

FOLLOWING extensive study of both present and future requirements for radar training aids, the Royal Norwegian Navy has placed an order with Solartron Radar Simulators Limited (a member company of the Solartron Electronic Group) for a new six target radar simulation system.

This order follows closely the delivery of other radar simulation systems to the governments of Germany, Italy and Sweden—all having been produced at the Farnborough (Hants) plant of the Solartron Electronic Group.

The equipment ordered will be delivered to the customer towards the end of 1959, and will provide realistic, intensive training facilities for radar operators and controllers. These personnel will be able to see radar responses and other data on their screens which will authentically simulate those produced under a wide variety of conditions, by actual ships and aircraft.

Data Processing Equipment

A COMPREHENSIVE installation of data processing equipment has been supplied to Canberra by Hollerith (Australia) Pty. Ltd., a subsidiary company of International Computers and Tabulators Ltd. It includes an electronic computer, electronic calculators, more than 20 tabulators, card sorters, four collators and interpreters, 12 mark-sensing reproducing summary punches, 40 automatic card punching and verifying machines, and a five-channel unit which converts information from perforated tape to punched cards.

£A4½m. Contract for English Electric

ENGLISH ELECTRIC has been awarded a contract to build Australia's first 200,000 kilowatt steam turbo-alternators for a new power station at Vales Point, 70 miles north of Sydney.

In a total contract worth £A4½m., negotiated by the company's Australian subsidiary, English Electric of Australia Pty., with the Electricity Supply Commission of New South Wales, the parent company will supply two turbo-alternators valued at about £3m. The remainder of the order will be manufactured in Australia to English Electric designs.

The new power station, when complete, will be the largest in the southern hemisphere.

Texas Instruments' £53,000 Study Contract

TEXAS INSTRUMENTS INCORPORATED have been awarded a £53,381 contract by the U.S. Air Research and Development Command to study a major semiconductor substrate device, the microminiature semiconductor solid circuit, developed by the company.

A substrate usually is an inactive supporting material, but in this case the substrate is a part of the functioning material.

The new semiconductor substrate device is expected to find great potential where large numbers of repetitive circuits are required, such as in the computer fields, rockets, missiles, satellites, and all space vehicle instrumentation where weight, size, and exceptional reliability are critical factors.

British Clock for Australia

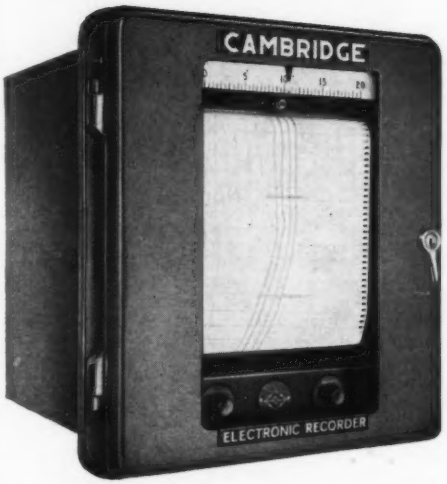
A CLOCK which will not gain or lose more than a second in 25 years is to be installed in the Australian Post Office Research Laboratories at Melbourne by a team of British scientists. The clock,

Circle 59 for further information

Cambridge

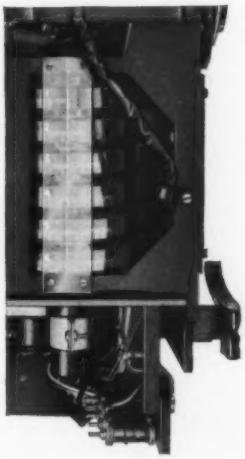
THE RECORDER-CONTROLLER

plus that extra something* which solves a lot of problems



Developed from the well-known, highly versatile and thoroughly proved Cambridge Electronic Recorder, this instrument provides all the usual control modes (i.e., ON-OFF [single and multi-point]; FLOATING; PROPORTIONAL [adjustable between 2% and 600%]; 3-TERM); and in addition:—

* a special feature is that with the ON-OFF control, each cam is individually adjustable, which means that each point is controlled *independently* of the other, at different settings if desired.



Send for List 186Y and Supplements. For future publications, ask for Mailing Form Y/4/59.

CAMBRIDGE INSTRUMENT COMPANY LTD.

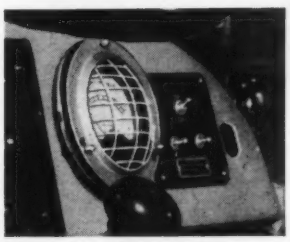
13 Grosvenor Place, London, S.W.1

Sifam

Instrumentation .. and the Antarctic Expedition

The Sno-cat tractors used in the expedition were perhaps one of the most significant factors contributing to its success.

The salient feature of their design and construction was to ensure their unfailing reliability under the extreme conditions to be encountered. The battery supply to the vehicles was naturally a vital consideration and it is significant to note that Sifam were chosen to supply the special instruments and equipment required to measure the temperature of the electrolyte which was kept at a working temperature by heating equipment supplied by Smiths Motor Accessories Ltd. Advice has since been received that although a complete set of Sifam spares was supplied, it was never required.



Section of Sno-cat dashboard showing special Sifam temperature indicator and control switch.

The Sifam Technical Representative will be glad to call and discuss your instrumentation requirements. Write or telephone now.

SIFAM ELECTRICAL INSTRUMENT CO. LTD.

Leigh Court, Higher Lincombe Road, Torquay, Devon.

Torquay 4547-8

SIFAM

Circle 60 for further information

known as an ammonia maser, has been constructed at the Ministry of Supply Signals Research and Development Establishment, Christchurch, Hants. It is accurate to within one ten thousandth of a second per day and will be the first of its kind in the southern hemisphere.

One job for which the maser will be used is the measurement of the rate at which electric pulses sent out by a radio transmitter near Rugby are received in Melbourne, some 15,000 miles away. Although the transmitting rate is constant the pulses are not received at a constant rate, due to variations in the ionosphere. The maser will be used to measure these variations, providing more information about the ionosphere.

Woden Transformers for Beirut

WODEN TRANSFORMER CO. LTD. has recently completed shipment of a consignment of 3-phase power transformers to the American University at Beirut.

The transformers are for use in the University Power Distribution Scheme and will be particularly valuable to students undergoing training at the University.

Swedish Order for Marconi

MARCONI'S WIRELESS TELEGRAPH COMPANY has been awarded a further contract worth £292,000 for television and sound broadcasting equipment by the Royal Board of Swedish Telecommunications. The equipment will play a major part in plans to give complete coverage to an area with nearly 7m. inhabitants.

British Nucleonic Gauges for Iraq

WHERE different kinds of fuel are pumped successively along the same pipeline, it can be a problem to tell just which fuel has reached any particular receiving point at any given time. This problem is solved with the recently developed Ekco fluid density gauge which uses gamma rays to ascertain from outside the pipe which kind of fuel is inside. Ekco Electronics Ltd. have just received an order for nine of these equipments from the Iraq Petroleum Co. Ltd. for installation along their 600-mile pipeline from Kirkuk in Iraq to Tripoli on the Mediterranean coast.

Japan Buys British Equipment

"ASAHI SHIMBUN", the Japanese newspaper, recently inaugurated a facsimile newspaper.

The *Asahi Shimbun* engineers first approached Muirhead two years ago having heard that Muirheads had functioning prototypes for this purpose. A model of the proposed machine was shown them, and they placed an order of £85,000.

By using a system of double channel transmission the designers have arranged the actual machines to work in pairs—this achieves two major objects besides the many technical advantages. They give the printer two complete newssheets together which he requires for his rollers. Furthermore, in case of, say, a power breakdown in any machine, a standby can immediately take over, with hardly any disruption in production.

The equipment will be in in full use printing on schedule five editions daily.

FORTHCOMING EVENTS

Oct. 9th. **The Society of Instrument Technology.** Midland Section. Gosta Green College of Technology, Birmingham, at 7-0 p.m. "Methods of testing electrical equipment used in the car industry." P. Luckhurst.

Oct. 13th. **The Society of Instrument Technology.** Manchester Section. Central Library, Manchester, at 6-45 p.m. "Instrumentation in the textile industry." L. H. C. Tippett.

Oct. 14th. **The British Institution of Radio Engineers.** London School of Hygiene and Tropical Medicine, Gower Street, London, W.C.1, at 6-30 p.m. Students' Meeting. "The use of transistors in communication and control." E. Wolfendale.

Oct. 14th. **The Society of Instrument Technology.** Data Processing Section. Manson House, 26 Portland Place, London, W.1, at 7-0 p.m. "An analogue computer for missile homing investigations." J. G. Thomason.

Oct. 15th. **The Society of Instrument Technology.** Tees-side Section. Cleveland Scientific & Technical Institute, Corporation Road, Middlesbrough, at 7-30 p.m. "An ultrasonic flowmeter." R. E. Fischbacher.

Oct. 20th. **The Society of Instrument Technology.** Bristol Section. University of Bristol, Department of Physics, at 7-30 p.m. "Feedback." R. S. Medlock.

Oct. 21st. **The Institution of Mechanical Engineers.** 1 Birdcage Walk, London, S.W.1, at 6-0 p.m. "Present-day feed-water treatment for high pressure boilers." P. Hamer.

Oct. 22nd. **The Institution of Production Engineers.** Royal Commonwealth Society, Northumberland Avenue, London, W.C.2, at 7-0 p.m. "Computers as applied to production control." B. L. J. Hart.

Oct. 29th. **The Society of Instrument Technology.** Chester Section. English Speaking Union, Stanley Palace, Watergate Street, Chester, at 7-0 p.m. "The industrial uses of computers." R. H. Tizard.

Oct. 29th **The Society of Instrument Technology.** Grangemouth Section. "Ellwyn" Restaurant, Newlands Road, Grangemouth, at 7-0 p.m. "Electrode problems in plant measurement." G. Mattock.

Oct. 30th. **The Society of Instrument Technology.** Scottish Section. Building Centre, Sauchiehall Street, Glasgow, at 7-15 p.m. "Instrumentation of Hunterston nuclear generating station." T. M. Dowal.

Nov. 3rd. **The Society of Instrument Technology.** Cheltenham Section. Belle Vue Hotel, Cheltenham, at 7-30 p.m. "Satellite instrumentation." S. J. Collins.

Nov. 12th. **The Society of Instrument Technology.** Tees-side Section. Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, at 7-30 p.m. "Analogue computers." R. E. Hare.

Nov. 13th. **The Society of Instrument Technology.** Midland Section. Gosta Green College of Technology, Birmingham, at 7-0 p.m. "Ultrasonic inspection techniques." W. B. Emms.

Nov. 17th. **The Society of Instrument Technology.** Bristol Section. University of Bristol, Department of Physics, at 7-30 p.m. "The gyroscope and its applications." W. H. McKinlay.

Nov. 19th. **The Society of Instrument Technology.** East Midland Section. College of Further Education, Greenclose Lane, Loughborough, at 7-15 p.m. "Vibration measurement." D. A. Drew.

Nov. 24th. **The Society of Instrument Technology.** Control Section. Manson House, 26 Portland Place, London, W.1, at 7-0 p.m. "Application of instrumentation to glass melting furnaces." N. I. Walker.

Nov. 25th. **The Society of Instrument Technology.** South Wales Section. Newport and Monmouthshire College of Technology, Newport, at 6-45 p.m. "Transistors." S. S. Goldberg

Nov. 26th. **The Society of Instrument Technology.** Grangemouth Section. "Ellwyn" Restaurant, Newlands Road, Grangemouth, at 7-0 p.m. "Magnetic meters." B. W. Balls.

Nov. 27th. **The Society of Instrument Technology.** Scottish Section. Building Centre, Sauchiehall Street, Glasgow, at 7-15 p.m. "Magnetic flow meter." B. W. Balls.

Publications Received

Guide du Contrôle Industriel 2nd edition, 1959, B.P.I. Editions.

This annual directory and guide to the French instrument industry covers manufacturers and agents of control, laboratory and testing instruments and gives useful information on official bodies, schools and trade organisations associated with the industry. The sections include an alphabetical index of instruments and accessories, an index of trade names, separate classified lists of manufacturers of measuring instruments, laboratory instruments, testing instruments, control and automation systems, instrumentation engineering and components and accessories.

Separate alphabetical indexes are also given of manufacturers, and of agents and importers.

British Petroleum Equipment 1959/60 edition, £2 10s. 0d., Council of British Manufacturers of Petroleum Equipment.

A list of members and a classified list of equipment and services offered are included together with members' catalogue entries.

Circle 61 for further information

The **HIGH** linearity **LOW** friction **TACHO**

The high linearity of the output of the L.S.E. direct current tachogenerator (resulting from the absence of an iron mass in the armature) is of particular value for use with computing or integrating systems.

Desirable 'low' characteristics include low inertia, low friction torque and low ripple content.

Abridged data:

D.C. output 20 volts into 20,000 ohms at 1,000 r.p.m.
Linearity 0·25% up to 1,500 r.p.m.
Temperature coefficient 0·013% per °C.
Ripple content less than 5% at 1,500 r.p.m.
Moment of inertia 0·52 oz - in.²
Friction torque less than 20 grm. cms.

For fuller details of this and other L.S.E. instruments, write to:

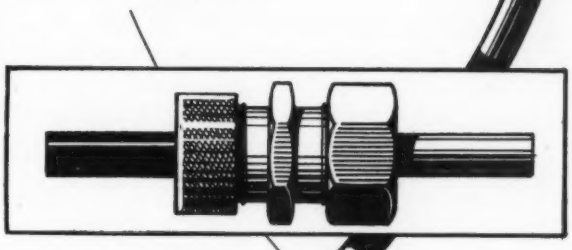
LAURENCE, SCOTT AND ELECTROMOTORS LTD.

Instrument Department, Openshaw, MANCHESTER

Circle 62 for further information

couplings

for copper



and plastic tubing

Here are the new WADE Couplings—specially designed for plastic tubing of all kinds. There's also a type for copper and plastic, and for copper tubing alone. WADE COUPLINGS are really efficient... capable of standing up to any normal pressure required. They're liquid-tight and gas-tight, and joints can be broken and re-made as often as necessary.

There's a size to fit every standard size tubing and there's a type to suit every kind of junction. Straight, Tee, Cross, Banjo and Elbow couplings will straighten out all the coupling problems you're likely to meet. We'll be delighted to send you FREE any type for testing or to help you with any special size required.

WADE

WADE COUPLINGS LTD.
37/49 East Road, London, N.1.
Tel. CLErkenwell 2534-5

PERSONALITIES

Griffin and George Appointments

Mr. Edward Bentley leaves Manchester, where he has been branch manager for two years, to take up the senior post of London branch manager.

Mr. Kenneth Freer, who was buyer at the Manchester branch, succeeds to the post of manager.

Mr. James Branson leaves his post as Yorkshire representative to become Manchester assistant branch manager.

Mr. Douglas Savage retains his post of field sales manager (Northern Area).

Mr. C. W. Moller

Mr. Charles W. Moller, B.E.M., tool room manager at the Plessey Company's Ilford factory, retired recently after 40 years of service.

Audco Engineering Co. Appointments

Mr. G. W. P. Scott, formerly senior technical sales engineer, has been appointed sales manager of the Audco Annin Products Division.

Mr. K. H. Lloyd, formerly senior technical engineer, has been appointed engineering manager of the Audco Annin Products Division.

Mr. Hans Bosshart has been appointed representative for the Benelux countries and will operate from Society Audco Belge S.A., 162 Avenue Louise, Brussels, Tel.: 47.26.39 and 47.87.92.

Mr. M. H. Ley

Mr. M. H. Ley, A.M.I.E.E., has been appointed sales manager to Westool Limited, St. Helen's Auckland. He was until recently manager of the Rectifier Equipment Engineering Department of the Rectifier Division of Standard Telephones & Cables Limited, where he had complete responsibility for the design and sales of all rectifier equipment.

Telephone Manufacturing Co. Appointments

Mr. Charles Hollingsworth Jackson, A.C.A., formerly vice-chairman and assistant managing director, has been appointed chairman of the Telephone Manufacturing Company and joint managing director. Mr. Patrick Bernard Healey, M.B.E., formerly the works director, has also been appointed joint managing director.

Mr. F. H. Parker

Fairey Aviation Ltd. announce the death of its engineering manager, Mr. Frederick Herbert Parker.

Sperry Gyroscope Board Changes

Mr. Robert Broadbent has been appointed chairman of the board of directors of the Sperry Gyroscope Co. and of Industrial Products (Speco) Ltd. and has been appointed chairman and managing director of the New Holland Machine Co. Ltd.

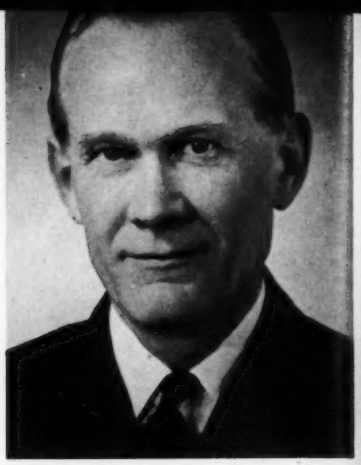
Mr. G. E. D. Whitaker has been appointed a director and retains his position as general manager of the New Holland Machine Co.

Mr. S. E. Spicer, a director of the parent company, has been appointed a director of Industrial Products (Speco) Ltd.

Captain R. A. Villiers

The Scientific Instrument Manufacturers' Association of Great Britain announced on 1st September the inauguration of SIMA's new director—Captain Robert Alexander Villiers, C.B.E., A.M.I.E.E., R.N.

At one stage in a long and eventful career, which included service in a high appointment during the Korean War, Captain Villiers was in command of H.M.



Captain R. A. Villiers

Underwater Countermeasures and Weapons Establishment of the Royal Navy at Havant—a research and development establishment.

In 1956 he attended the Imperial Defence College. Subsequently—until this year—he was the United Kingdom Naval Representative with the N.A.T.O. Military Agency for Standardisation and Chairman of the Naval Board in London. In January 1959 he was appointed a Naval A.D.C. to Her Majesty The Queen.

Mr. K. Fearnside

Mr. K. Fearnside has been appointed to the Board of Smiths Aircraft Instruments Ltd. as director of research. Formerly research manager at the company's Cheltenham factory, Mr. Fearnside will continue to have charge of research activities in his new appointment.

Executive Board for Semiconductors Ltd.

Semiconductors Limited announce the formation of an Executive Board headed by Dr. J. Reekie, executive director and general manager. Mr. C. H. Noton, who recently joined the Company as commercial manager, becomes commercial executive director. Mr. E. E. Webster, central production executive, Swindon Region of The Plessey Company Ltd., has also been appointed an executive director of Semiconductors Limited.

Mr. C. G. Hutchinson

The Data Recording Instrument Company Limited of Ashford, Middlesex (an associate company of International Computers and Tabulators Limited) announce the appointment of Mr. C. G. Hutchinson as general sales manager.

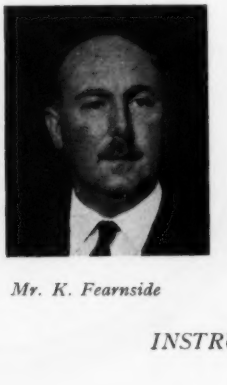
Dr. A. G. J. Buckle

Dr. A. G. J. Buckle, M.Sc., Ph.D., A.R.I.C., has been appointed technical director of Technicon Instruments Co. Ltd. Prior to this he was chief chemist of the Helsby Division of British Insulated Callender's Cables Ltd. A graduate of Liverpool University, he spent two years on research work at their University and later at Zurich.

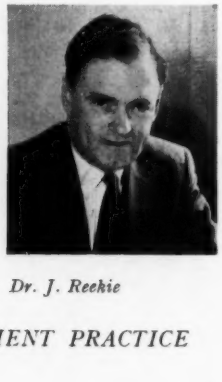
Mr. R. H. Powell

Mr. R. H. Powell has relinquished his appointments with the Griffin & George Group of Companies.

Mr. M. H. Ley



Mr. K. Fearnside

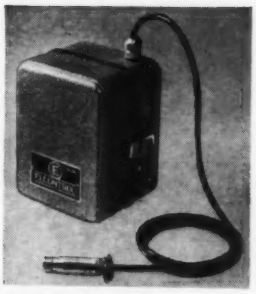


Dr. J. Reekie

Circle 63 for further information

photoelectric controls

small—and very accurate



a compact unit in a variety of types

THE new Elcontrol photo-relays, viewing heads and scanners have been made small so that they can be used freely on modern precision machines.

They operate with a very narrow light beam, and are very sensitive. They open up a new conception of high speed close tolerance automatic control throughout the manufacturing and handling industries.

Elcontrol photoelectrics are ideal for control jobs where movement has to be detected — tell us what you want to do and we will gladly help you.

Appointed Agents	*Telephone*
MIDLANDS: A. M. Lock & Co. Ltd., Newborough Rd., Solihull.	*Shirley 5703*
N. WEST: A. M. Lock & Co. Ltd., Union St., Oldham.	*Main 6744*
SCOTLAND: A. R. Bolton & Co., 3a St. Vincent St., Edinburgh 3.	*32035*

write to **ELCONTROL LTD., HITCHIN, HERTS.** *Hitchin 2411*

ELCONTROL

MUREX SINTERED PERMANENT MAGNETS are used in this SANGAMO WESTON HOMING INDICATOR

Four Murex magnets are used in the movement assembly of this hermetically sealed aircraft homing indicator by Sangamo Weston Ltd. In this application, as in many others, Murex Sintered Permanent Magnets provide high flux density and magnetic stability in a small area.

For technical information on the design, performance and characteristics of Murex Permanent Magnets write for a copy of the new Magnets Catalogue. Technical representatives always available for consultation and advice.

Actual size of Magnet

Photograph by courtesy of Sangamo Weston Ltd.

MUREX LIMITED *(Powder Metallurgy Division)*

RAINHAM · ESSEX *Telephone: Rainham, Essex 3322. Telex 28632. Telegrams: Murex, Rainham-Dagenham Telex*

LONDON SALES OFFICE: CENTRAL HOUSE, UPPER WOBURN PLACE, W.C.1. *Telephone: EUSton 8265*

Circle 64 for further information

Circle 65 for further information

Precision Electrical Measuring Instruments

BY Ernest Turner

Ernest Turner precision-built electrical measuring instruments give absolute accuracy, dependability and ease of reading and keeping pace with the ever widening field of electronics, Ernest Turner Electrical Instruments offer a wide range of instruments to meet specific requirements and individual applications. For more than 35 years, in this country and in many parts of the world, wherever there has been a job of precise electrical measurement to be done, the choice has been Ernest Turner instruments

Ernest Turner Electrical Instruments Ltd. HIGH WYCOMBE · BUCKS · ENGLAND

Telephone: High Wycombe 1301-2-3 *Cables: Gorgeous, High Wycombe*

Pressure, Vacuum & Temperature Gauges

We have a wide range of Pressure, Vacuum Altitude, Compound, Combined Altitude and Pressure and Temperature Gauges.

Full details of Types are contained in our Catalogue which is available on request.

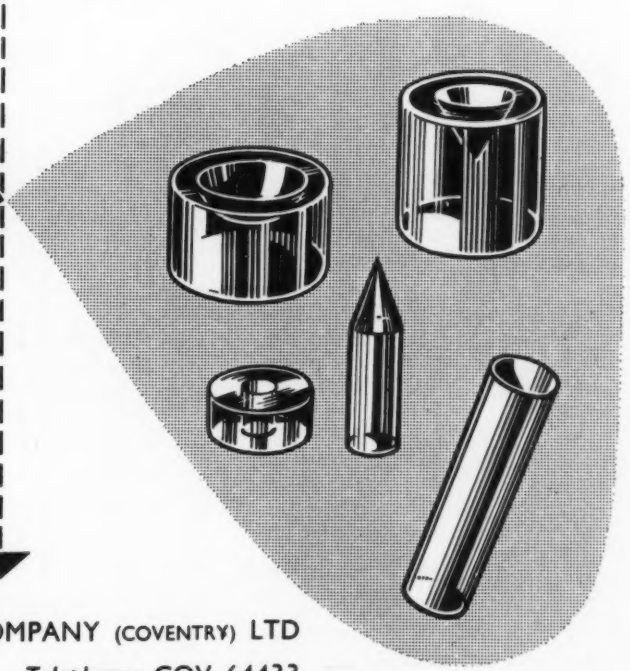
We can manufacture and supply Pressure Gauges from 1" dia. to 24" dia. In ranges of pressures from 5 to 20,000 lbs sq. in.

Full details from Branch Office

TOMEY INDUSTRIES LTD BIRMINGHAM 6 ENGLAND

JOSEPH TOMEY & SONS Catherine Street, Aston, Birmingham, England
Telephone : East 1786 P.B.X.

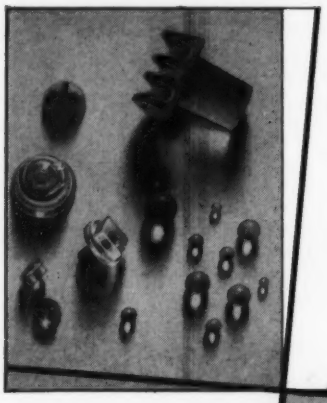
All types of Synthetic Sapphire Instrument Bearings



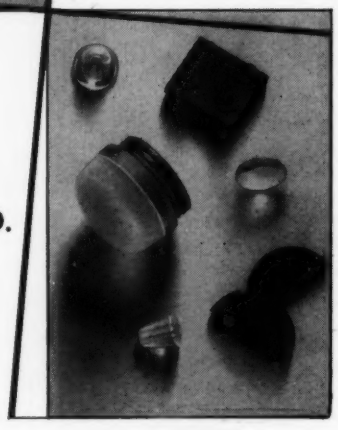
Also suppliers of diamond saws and waxes for the crystal cutting industry.
Specialists in the cutting to length of small glass tubing up to $\frac{1}{4}$" diameter.

FRED LEE & COMPANY (COVENTRY) LTD
DOVER STREET · COVENTRY *Telephone:* COV 64433

Circle 67 for further information



PRECISION GLASS MOULDERS FOR 25 YEARS



The
ENGLISH
GLASS CO. LTD.
EMPIRE ROAD
LEICESTER
Phone 23481/2

EGC

Type LP 2

PENNY & GILES
MUDEFORD · CHRISTCHURCH · HANTS
TELEPHONE HIGHCLIFFE 2855

RECTILINEAR POTENTIOMETERS
FOR REMOTE INDICATION AND RECORDING OF DISPLACEMENT

STROKE LENGTHS
Up to 9 inch for Type LP 2
Up to 24 inch for Type LP 1

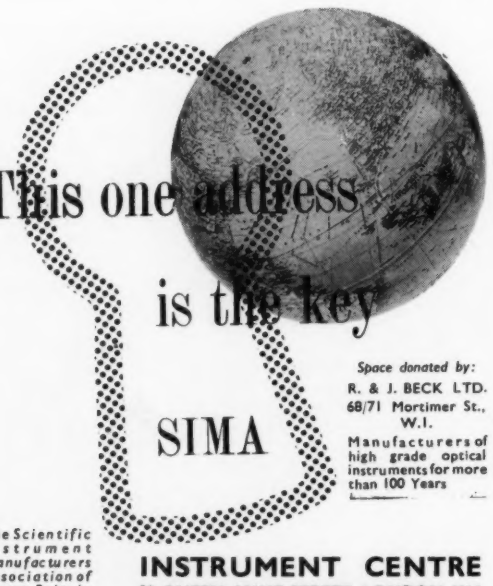
TWO RESISTANCE ELEMENTS

AMBIENT TEMPERATURES
Available for use in the following ranges
−50°C to + 85°C
−50 C to +150°C
−50°C to +250°C

RESOLUTION of 0·001 inch can be achieved

WRITE FOR DATA SHEETS

Also manufacturers of potentiometers in size 11 and size 15 synchro mountings.
Single and multi-gang. Single and multi-turn.



This one address is the key

SIMA

Space donated by:
R. & J. BECK LTD.
68/71 Mortimer St., W.1.
Manufacturers of high grade optical instruments for more than 100 Years

The Scientific Instrument Manufacturers Association of Great Britain

INSTRUMENT CENTRE
20 QUEEN ANNE STREET, LONDON, W.1
Tel: IMPerial 6000 (Press enquiries: LANgham 4251)
Here the whole world can find the finest scientific instruments, key information and prompt advice.

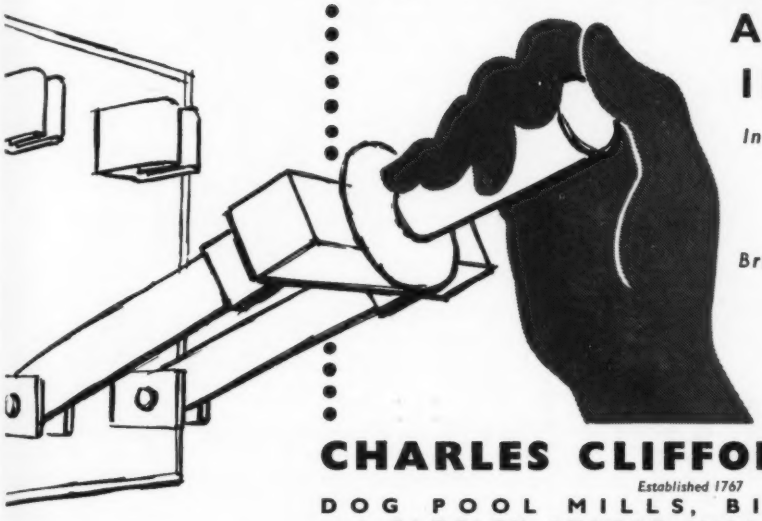
HIGH RESOLUTION RECORDING
A.R.L. TYPE 'E'

THIS INSTRUMENT WILL RECORD, FOR ANALYSIS TO 1%, 50 C.P.S. AT 8"/SEC. AT AN AMPLITUDE OF ·08".
FILM 35 MM. PERFORATED OR UNPERFORATED.
CAPACITY 30 FT.
9/10 CHANNELS.
DATUM TRACE.
TIME MARKER.
TRACE IDENTIFICATION BY TRACE BREAK OR COLOUR FILM.
D.C. P.M. MOTOR 3 – 75 VOLTS.
5 SPEEDS, ¼" TO 8"/SEC.
SELF OPENING DAYLIGHT CASSETTES.
FOOTAGE INDICATOR.
SPOT SETTING GRATICULE.
A.R.L. MIDGET GALVANOMETER.
NATURAL FREQUENCY RANGE 60, 100, 108, 125, 250 C.P.S.
ACCESSORY NEON EVENT MARKER.
SIZE 8½" × 4½" × 2¾".
WEIGHT 7¾ LBS.

WOODHILL ENGINEERING CO. LTD.,
TROUT ROAD, YIEWSLEY, MIDDLESEX
TELEPHONE: WEST DRAYTON 3168 & 2892

PHOSPHOR BRONZE

FOR THE ELECTRICAL AND ASSOCIATED INDUSTRIES



In a range of alloys containing 3%—12% Tin, for specific purposes, to private specifications and to British Standard Specifications

STRIP & SHEET
ROD, WIRE, TUBE
CHILL CAST BARS

CHARLES CLIFFORD LIMITED

Established 1767

DOG POOL MILLS, BIRMINGHAM 30
and FAZELEY STREET MILLS, BIRMINGHAM 5
OFFICES: LONDON, GLASGOW, DUBLIN

H-W.133

COMPENSATING AMPLIFIERS BY STERNS!

The output current of the Compensating Amplifier is directly proportional to the input signal (d.c. current or voltage).

Amplifiers are used for the following applications:

Wattless amplification of small d.c. voltages and currents of the type appearing in the output circuit of chemical and physical active or inactive transmitters.

Tele-transmission of measured values which can be represented as d.c. voltages or currents (temperatures by means of thermocouples or resistance thermometers, mechanically measured quantities by means of resistance transmitters). This system is suitable for transmission distances of up to 60 miles.

Constant-Current Source

The Constant-Current Source supplies a constant direct current of 5 mA and serves for:

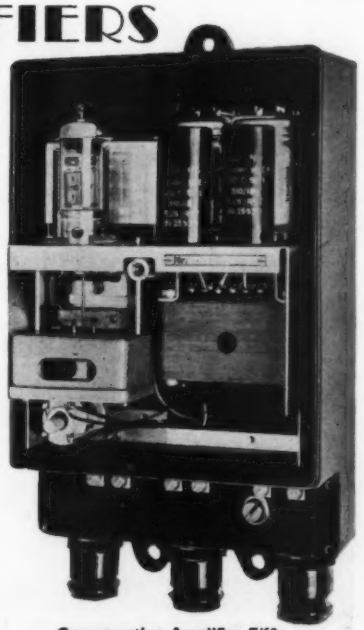
Conversion of resistance values into d.c. voltages at the measuring of temperatures by means of resistance thermometers operating in conjunction with a Compensating Amplifier.

Supplying the operating current of resistance transmitters in tele-transmission systems.

Electrical zero suppression in moving coil instruments.

Supplying the operating current for bridge circuits to which moving coil instruments are connected.

WRITE FOR LEAFLET EK3e



Compensating Amplifier EK3e

OTHER INSTRUMENTS MANUFACTURED BY STERNS

Strip Chart Recorders.
Radiation Pyrometers, of the Thermo-electric type, range 1400 deg. C.
Edgewise Temperature Indicators. Temp. On/Off Controllers.

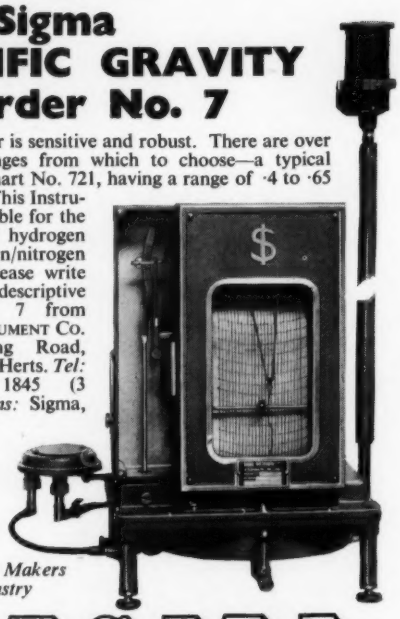
C. T. STERN INSTRUMENTS (GREAT BRITAIN) LTD.

21 DEVONSHIRE STREET, LONDON, W.1

Circle 74 for further information

The Sigma SPECIFIC GRAVITY Recorder No. 7

The Recorder is sensitive and robust. There are over 30 chart ranges from which to choose—a typical example is chart No. 721, having a range of ·4 to ·65 (air = 1·0). This Instrument is suitable for the detection of hydrogen in hydrogen/nitrogen mixture. Please write for fully descriptive leaflet No. 7 from SIGMA INSTRUMENT CO. LTD., Spring Road, Letchworth, Herts. *Tel:* Letchworth 1845 (3 lines) *Grams:* Sigma, Letchworth.



Instrument Makers to Industry

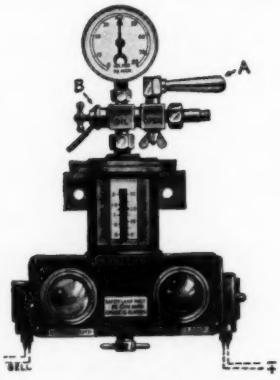
SIGMA
INSTRUMENT CO. LTD.

FWS

Circle 75 for further information

SPECIFY

"MONITOR"



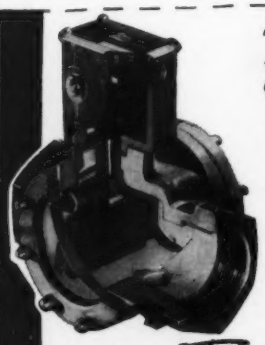
"Monitor" Pressure Alarm, Design 9

WHITE LAMP FOR SAFETY RED LAMP FOR DANGER

The Indicator Panel is combined for simplicity in wiring and erection. The alarm range is adjustable and can be tested in service. For forced lubrication systems, etc.

C.L. Stokoe Patents Reg. Trade Mark "Monitor"

"MONITOR" PATENT SAFETY DEVICES LTD.
WALLSEND-ON-TYNE



Risk!

eliminated

Failure of, or variation inflow, pressure or temperature is instantly recorded by the

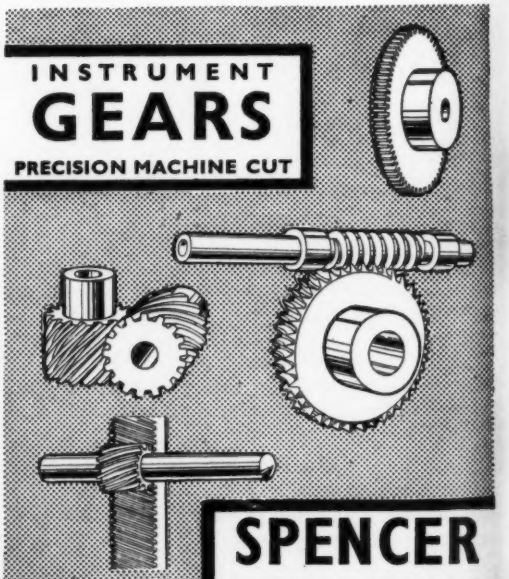
AJAX *Flow* INDICATOR

Available in 1" to 6" pipe sizes, screwed or flanged

BAMFORDS
OF STOCKPORT

F. BAMFORD & CO. LTD., STOCKPORT, CHESHIRE. Tel.: Stockport 6507-9

INSTRUMENT
GEARS
PRECISION MACHINE CUT



Telephone: Highbury 3155

SPENCER
COMPONENTS
5 HIGH STREET
BIRMINGHAM - 14

Circle 76 for further information

Circle 77 for further information

Circle 78 for further information

THERE OUGHT TO BE ANOTHER NAME

So many people think that a microscope is only at home in the shelter of the Laboratory.

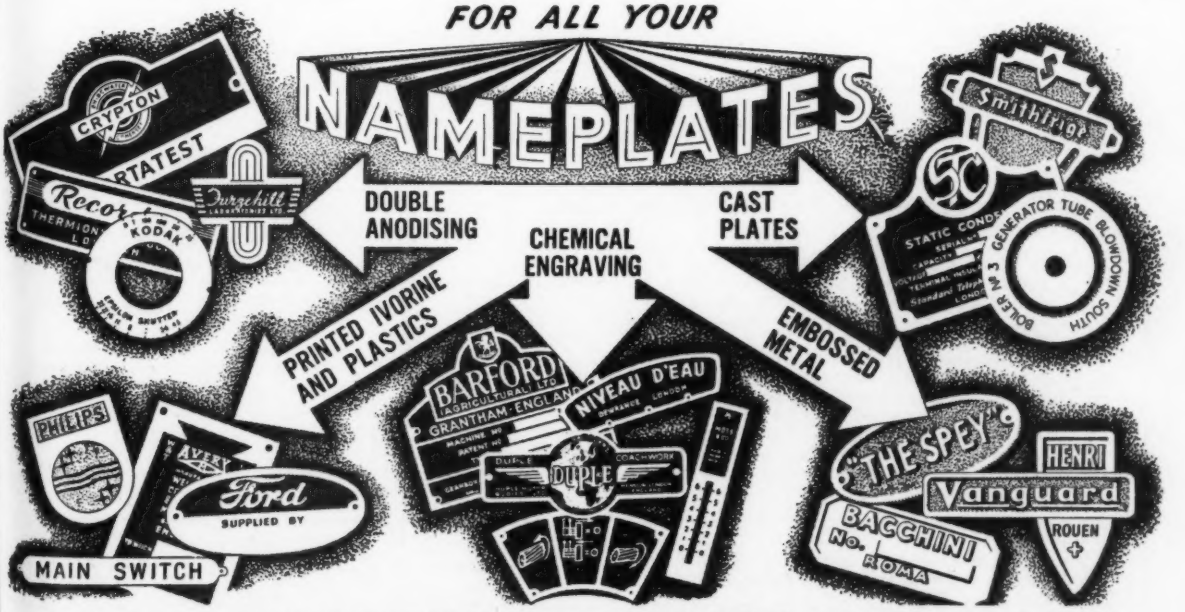
BUT THESE ARE MICROSCOPES — and very fine ones, new precision tools designed for industry. Made for the machine shop, the assembly bench and the inspection room, bringing graphic, three-dimensional vision to bear on every problem of precision. Widely adaptable to suit every need, strongly constructed for a long life of continuous service.

Our List 6E gives all the details. May we send a copy?

W. Watson & Sons Ltd., Barnet, Herts.

MILLETT, LEVENS (ENGRAVERS) LTD.

STIRLING CORNER, BARNET BY-PASS, BOREHAM WOOD, HERTS. 'Phone ELStree 2871 (10 Lines)



NAMEPLATES OF EVERY DESCRIPTION FOR SCIENTIFIC INSTRUMENTS - IN ANY COLOUR OR FINISH

INCLUDING SELF-ADHESIVE NAMEPLATES

Circle 79 for further information

CLASSIFIED ADVERTISEMENTS

All advertisements must be PREPAID. Situations Wanted, 4d. per word. Minimum 6s. All other advertisements, 6d. per word, minimum of 10s. Semi-display advertisements, 4s. per line. Minimum £2. Display advertisements at tariff rates. Box Numbers count as four words. Replies forwarded 1s. extra. Replies to Box Numbers must be addressed to *Instrument Practice*, 9 Gough Square, Fleet Street, London, E.C.4.
The Proprietors reserve to themselves the right to refuse to insert an advertisement if they think proper to do so. All possible care is taken to ensure accuracy in setting up the advertisements, but should an error be made the Proprietors will not hold themselves responsible in any way for same.

SITUATIONS VACANT

ELECTRONICS ENGINEER required by a prominent Surgical House for sales service of advanced electronic hospital equipment. Membership of a senior engineering institute required together with experience of similar equipment. This is an interesting new departure and offers every opportunity for advancement. Apply giving full details of age, qualifications and experience to Box 718.

INSTRUMENT MECHANIC

KODAK LIMITED

have a vacancy for an Instrument Mechanic on a shift work basis. The work involves installation and maintenance of indicating, recording and controlling instruments for process, air conditioning and power station operation.

An apprenticeship plus previous experience in industrial instrumentation essential.

Average earnings, after a short preliminary period, will total £18 10s. 0d. per week. In addition a merit rating scheme is in operation as well as free sickness and pension plans.

Please write or call:

Men's Personnel Department,
Kodak Limited (Factories),
Wealdstone, Harrow, Middlesex.

THE DISTILLERS COMPANY LIMITED

INSTRUMENT DRAUGHTSMAN

The Distillers Company Limited have a vacancy at their Devonshire House Engineering Office, in the West End, for a male Instrument Draughtsman. Candidates, aged between 25 and 40, must hold a Higher National Certificate in Electricity. They should also have considerable experience in design and drawing of instrumentation of automatic control installations, preferably for chemical or plastics plants.

Write:
Staff Manager,
The Distillers Company Limited,
21 St. James's Square,
London, S.W.1.
Quote Ref. 96/59.I.P.

INSTRUMENT ENGINEER MECHANIC required by Lancashire Tar Distillers Ltd., for their Engineering Department. This will be a staff position with membership of pension scheme. Canteen available. Applicants should have a good experience of modern industrial instruments, including both electric and pneumatic types. Application in confidence to Chief Engineer, Lancashire Tar Distillers Ltd., Engineering Department, Liverpool Road, Cadishead, near Manchester.

IMPERIAL CHEMICAL INDUSTRIES LIMITED, Plastics Division, notifies the following vacancies:—

(i) Two Assistant Technical Officers for work on instrument maintenance. Applicants should hold the H.N.C. in Mechanical/Electrical Engineering or Applied Physics, and have had some experience of instrumentation either in the fields of design, erection or maintenance, including instrument workshop experience.
(ii) Two Assistant Technical Officers (Draughtsmen) for work in instrument design. Applicants should hold or be studying for the H.N.C. in Electrical or Mechanical Engineering and have had some experience of instrumentation, possibly as an ex-instrument artificer apprentice.
(iii) One Laboratory Assistant for work on the development of electronic instrumentation, including the use of pulse techniques. Applicants should hold or be studying for the O.N.C. with, if possible, some experience in electronics.

The Company works a five-day week of 39 hours, and pension and profit sharing schemes are in operation.

For married men some help would be given towards removal expenses. Temporary lodging allowances also available.

Apply briefly to the Staff Manager, Imperial Chemical Industries Limited, Black Fan Road, Welwyn Garden City, Herts.

WANTED, Representatives for correspondence abroad, high earnings, written instructions. Write, IFD, Vienna 66, Postfach 128.

REPRESENTATIVE

required by Microscope Makers to call on Technical Colleges and Universities throughout the country.

Salary and Commission £900-£1,100; expenses and car allowance.

Applications in writing to:—

Chief Personnel Manager,
James Swift and Son Ltd.,
98 St. Pancras Way, N.W.1.

AN old established manufacturer of Dial Thermometers, Recorders and Air-operated Controllers with mercury in steel and vapour filled systems, located in the United States, wishes to engage the services of a thoroughly competent manufacturing mechanic who is presently employed in the manufacture of the above items. He must be able to make all parts and assemblies, weld, silver solder, braze and calibrate the instruments. There is a permanent position and a good opportunity for such a man, with starting pay based on a 40-hour week of £32 rising to £38 per week. Send airmail complete résumé of your apprenticeship and practical ability, age and recent photo to Scientific Instrument Company, 1041 Second Avenue, Detroit 26, Michigan, U.S.A.

SERVICES AVAILABLE

GEARS FOR INSTRUMENTS mass produced to customers' own requirements by specialists. THE DAVALL GEAR CO. LTD., Gear Works, High Street, Potters Bar, Middlesex. Telephone: Potters Bar 2382-3.

PRECISION ENGRAVING of Instrument Panels, Dials, Scales, Nameplates, Labels, etc., Plastic Components, "Perspex" fabrications. Stockists of "Perspex" acetate, Traffolyte, etc. Speedy deliveries on long or short runs. A.I.D. and A.R.B. approved. Leicester Engravers (Plastics) Ltd., 60 Edwyn Street, Leicester. Telephone: Leicester 58375.

'Acleera'

Crystals

Unbreakable glasses for watches, clocks and instruments.

Manufacturer of any shape or style of plastic transparent cover for protective and viewing purposes on all types of mechanisms or instruments.

C. N. BROWNE
14 Abbotts Road, Cheam. Surrey
Telephone: Fairlands 3314

MIRRORS re-silvered or re-aluminised promptly to very high standards at moderate prices. Front or back silvering including heat-resisting silvering, or surface aluminising. New mirrors supplied. Over 50 years' experience of mirror manufacturing. GOWLLANDS LTD., Morland Road, Croydon. Telephone: Addiscombe 3011.

MACHINE ENGRAVED SCALES, Feed Dials, Panels, Labels, etc., in plastic and metal. Excellent delivery. O. H. Kampf & Co., 15a Market Square, Crewkerne, Somerset.—Telephone: Crewkerne 709.

DEVELOPMENT OF NEW PROJECTS
Designing, Drawing, Detailing Prototypes. Small quantity manufacture. Special purpose machines. Instrument work a speciality. Inventions worked out
A. RUNDLE (Upper Norwood) LTD.
Micro Works, Stoney Lane, Church Road, Upper Norwood, London, S.E.19
Enquiries and quotations invited
Telephone: LIVingstone 4682

THERMOMETERS, Scientific & Industrial, Glass and metal components. Enquiries to J. McKenzie & Son, 40 Rosoman Street, London, E.C.1. Telephone : Terminus 7533.

SPINNINGS
IN ALL METALS
Hydraulic and Flow Spinning Specialising for the Electronic and Instrument Industries.
★
Hydraulic Presswork
Argonarc & Spot Welding
★
E. J. PURDIE & SON LTD.
49-53 CORSICA STREET, HIGHBURY, N.5.
Telephone: Canonbury 2128

SPENCER COMPONENTS
5 High Street, Birmingham, 14

STANLEY
undertake high class
Precision Engineering
—
Complete Instruments
or
Components
—
Enquiries invited
(please quote reference I.P.I.)
W. F. STANLEY & Co., Limited,
New Eltham,
London, S.E.9.
(Phone:—ELTHAM 3836)

LABORATORY STAINLESS STEEL EQUIPMENT & PROTOTYPES
Manufactured to customers' own requirements
BOSS
WELDING & ENGINEERING Co. Ltd.
190 PENTONVILLE ROAD, LONDON, N.1
Telephone: Terminus 3598

MACHINE ENGRAVING
one off or small batches
Indexing Dials and Scales divided.
Instrument Components a Speciality.
A. RUNDLE (Upper Norwood) LTD.
Micro Works, Stoney Lane, Church Road, Upper Norwood, London, S.E.19
Telephone: LIVingstone 4682

INSTRUMENT, WATCH AND CLOCK MATERIALS AND PRECISION TOOLS
Broaches — Lathes
Pivot Steel — Staking Sets
Tweezers & Pliers — Cleaning Machines

Polystyrene Specimen Boxes
(Send for illustrated Catalogues and Price List)
JOHN MORRIS (Clerkenwell) LTD.
64 Clerkenwell Road, London, E.C.1
Clerkenwell 6077

THE INDUSTRIAL APPLICATION
OF
pH MEASUREMENT AND CONTROL
by
D. Colver Nutting, M.B.E., A.R.C.S., B.Sc.

In a wide variety of industries the measurement and control of pH is a necessity. Typical examples of processes are sugar refining, water treatment, ore flotation, etc.
The author has given a concise treatment of the subject in the five articles now available as a bound set of reprints. The underlying principles are reviewed and the derivation of the pH scale explained. Methods of measurement and control are detailed, and the application to a variety of typical continuous processes is outlined. The problem of close control is dealt with by the Author.
Practical requirements during installation are specified.
Price 5/- (Post free)
UNITED TRADE PRESS LTD. 9 Gough Square, London E.C.4

A COURSE IN INDUSTRIAL INSTRUMENT TECHNOLOGY
BY
J. T. MILLER, B.Sc., F.Inst.P.

So great has been the demand for reprints of Mr. Miller's *Course in Industrial Instrument Technology* that the supply was soon exhausted, and a more convenient new edition, produced by the photo-litho process and bound in stout paper covers, is now available.

CONTENTS
I. Basic Elements or Mechanisms.
II. Diaphragms.
III. U-Tube Manometers.
IV. Flow Metering Elements for Fluids in Pipes.
V. Flow Metering Elements for Fluids in Pipes (*continued*).
VI. Measuring Instruments for Differential Flow Elements.
VII. Flow Measurement: Integration from Differential Pressure Instruments.
VIII. Area Meters: Rotameters and Flowrators.
IX. Anemometers, Electrical Flow Meters and Quantity Meters.
X. Electrical Methods.
XI. Electrical Methods (*continued*): Resistance Thermometers.
XII. Radiation Temperature Measuring Instruments.
XIII. Humidity Measurement.
XIV. Industrial Electronic Instruments for the Measurement (and control) of Temperature, Pressure, Flow, etc.
XV. Electronic Instruments (*continued*).
XVI. Automatic Control.
XVII. Automatic Control (*continued*).
XVIII. Automatic Control (*concluded*).

Price **20/-** post free
Send your order to:
UNITED TRADE PRESS LTD.
9 GOUGH SQUARE
FLEET STREET, LONDON, E.C.4

Circle 80 for further information

THE

E. & H. FILTER CO. LTD.

Specialists in the production of all types of

METAL GAUZE FILTERS

to your own Specifications

MAY WE ADD YOU TO OUR LIST OF CUSTOMERS

which includes the following famous concerns:

A.C. DELCO A.E.C. BRITISH OXYGEN B.S.A. CHRYSLER
DAIMLER MAUDSLEY PARKINSON-COWAN
PLESSEY RUBERY OWEN S.I.F. VILLIERS

ASHLEY WORKS, ASHLEY ST., LONG LANE, BLACKHEATH, BIRMINGHAM.

Telephone: BLAckheath 1638

Circle 81 for further information

GLASS

All Glass Requirements for Scientific Instrument Manufacturers and Research Workers

- SHEET & PLATE GLASS—cut and ground to exact dimensions
- LENSES, PRISMS & FLATS — to any standard of accuracy
- MIRRORS — back silvered and front surface aluminised, etc.
- BLOOMING of optical components

C. J. WHILEMS, LTD.

ILFORD OPTICAL WORKS

FOREST ROAD, BARKINGSIDE ESSEX

Telephone: HAInault 5454-5

A Course in Industrial Instrument Technology

by

J. T. MILLER,

B.Sc., F.Inst.P.

This Course, which appeared originally as a serial in the technical journal, *Instrument Practice*, is the first of its kind to be published from British sources.

So great has been the demand for reprints of Mr. Miller's *Course in Industrial Instrument Technology* that the supply was soon exhausted, and a more convenient new edition, produced by the photolitho process, and bound in stout paper covers is now available.

Contents

I Basic Elements or Mechanisms.
II Diaphragms.
III U-Tube Manometers.
IV Flow Metering Elements for Fluids in Pipes.
V Flow Metering Elements for Fluids in Pipes (*continued*).
VI Measuring Instruments for Differential Flow Elements.
VII Flow Measurement: Integration from Differential Pressure Instruments.
VIII Area Meters: Rotameters and Flowrators.
IX Anemometers, Electrical Flow Meters and Quantity Meters.
X Electrical Methods.
XI Electrical Methods (*continued*): Resistance Thermometers.
XII Radiation Temperature Measuring Instruments.
XIII Humidity Measurement.
XIV Industrial Electronic Instruments for the Measurement (and control) of Temperature, Pressure, Flow, etc.
XV Electronic Instruments (*continued*).
XVI Automatic Control.
XVII Automatic Control (*continued*).
XVIII Automatic Control (*concluded*).

Price 20/- (post free)

UNITED TRADE PRESS LTD., 9 GOUGH SQUARE, LONDON, E.C.4

Circle 82 for further information

Circle 83 for further information

How important is

SURFACE FINISH CONTROL?

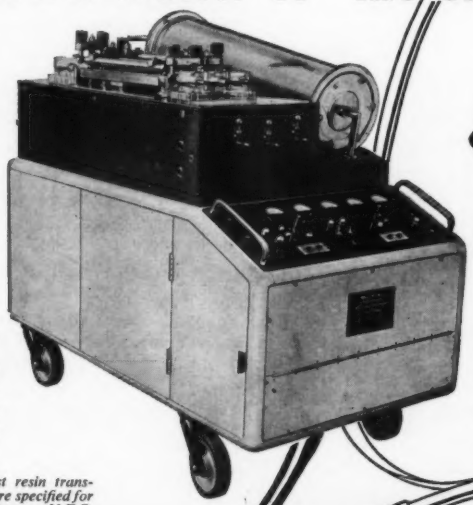
Are your Draughtsmen, Foremen, Inspectors, and Machinists surface finish conscious? If so your products will have a high reputation; if not, your products will not be classed as high quality. "RUBERT" Surface Roughness Scales provide a reference of calibrated Surface Roughness for comparison of machined surfaces by sight and touch, and fulfil the need for a simple, dependable standard for visualising, selecting and specifying surface conditions for production work. Whether you have electronic instruments to test Surface Roughness or not, your Draughtsman always needs Surface Roughness Standards to enable him to specify the required surface finish, and the Machinist cannot be without these because he must always have a comparison handy to tell him whether the finish is good enough, not good enough, or too good. We supply complete sets and single standards for special requirements to B.S.S. 1134: 1950, and B.S.S. 2634/1: 1955. Accuracies 10% or 20%

We are exhibiting at:—
6th EUROPEAN MACHINE TOOL EXHIBITION — PARIS
September 12th — 21st
STAND No. 4F1

RUBERT— SURFACE ROUGHNESS SCALES

RUBERT & CO. LIMITED
ACRU WORKS, DEMMINGS ROAD, COUNCILLOR LANE, CHEADLE, CHESHIRE
Telephone: GATley 5855

When it's a matter of "life or death"



WODEN TRANSFORMER CO. LTD.

You will find Woden Transformers specified for reliability on precision instruments of every type.
Rigid construction and careful assembly combine to guarantee absolute reliability throughout many years of service.
Catalogues available on all types of transformers.

Woden cast resin transformers were specified for the Melrose N.E.P. Heart and Lung Machine

WODEN TRANSFORMER CO. LTD
MOXLEY ROAD BILSTON : STAFFS
Phone: BILSTON 42681

Circle 84 for further information

Circle 85 for further information

Communications Receivers in stock at WEBB'S

The G.E.C. 'BRT 400K' - £190

Tunes 150-385 Kc/s and 0·51-30 Mc/s in six bands. Very comprehensive specification includes integral crystal calibration, variable selectivity, crystal filter, audio filter, highly efficient A.G.C.

EDDYSTONE '680X' £120.0.0
480 Kc/s to 30 Mc/s in five bands.

EDDYSTONE '840A' £55.0.0
480 Kc/s to 30 Mc/s in four bands.

EDDYSTONE VHF '770R'
19 to 165 Mc/s

EDDYSTONE UHF '770U'
150 to 500 Mc/s

EDDYSTONE '730/4'
general coverage

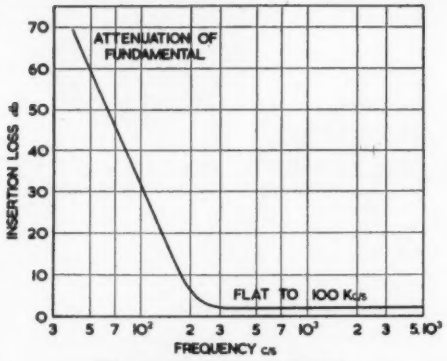
All Ex Stock at

WEBB'S RADIO

14 Soho St., Oxford St., London, W.1. Tel: GERrard 2089/7308

Shop Hours: 9-5.30 p.m. (Thursdays 7 p.m.) Saturdays 9-1 p.m.

ELECTRIC WAVE FILTERS



The curve illustrates typical high pass filter characteristics

★ **LC and RC filters based on modern theory, techniques and components**

★ **Low or high pass, band pass, or band stop filters can be designed to individual performance specification**

BARR & STROUD LTD.

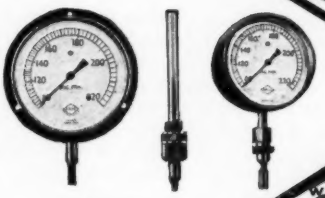
Registered Office and Works:
ANNIESLAND
GLASGOW, W.3

London Office:
Kinnaird House
1 Pall Mall East, S.W.1

Circle 86 for further information

ACCURATE RECORDING INSTRUMENT CO.

vapour pressure thermometers for industry



ARIC

WINDSOR AVENUE
MERTON, S.W.19 Liberty 5661/2/3

INFORMATION WITH PLEASURE

manufactured under ideal conditions backed by years of experience and know-how

ACCURATE ARIC INSTRUMENTS

PRESSURE GAUGES INDICATING AND RECORDING
TEMPERATURE DIAL THERMOMETERS RECORDERS CONTROLLERS
THERMOSTATS INDICATING AND NON-INDICATING
VACUUM GAUGES
CONTROLLERS TEMPERATURE PRESSURE · CONTENTS LEVEL

IRISH SUBSIDIARY
ARIC (IRELAND) LTD
8 MONTAGUE ST., DUBLIN

CLASSIFIED ADVERTISEMENT

If you want to emphasise your firm's services or equipment; if you wish to advertise a vacant situation, buy or sell equipment, the Classified Advertisement columns of "INSTRUMENT PRACTICE" will prove a valuable medium for your announcement—and bring results quickly.

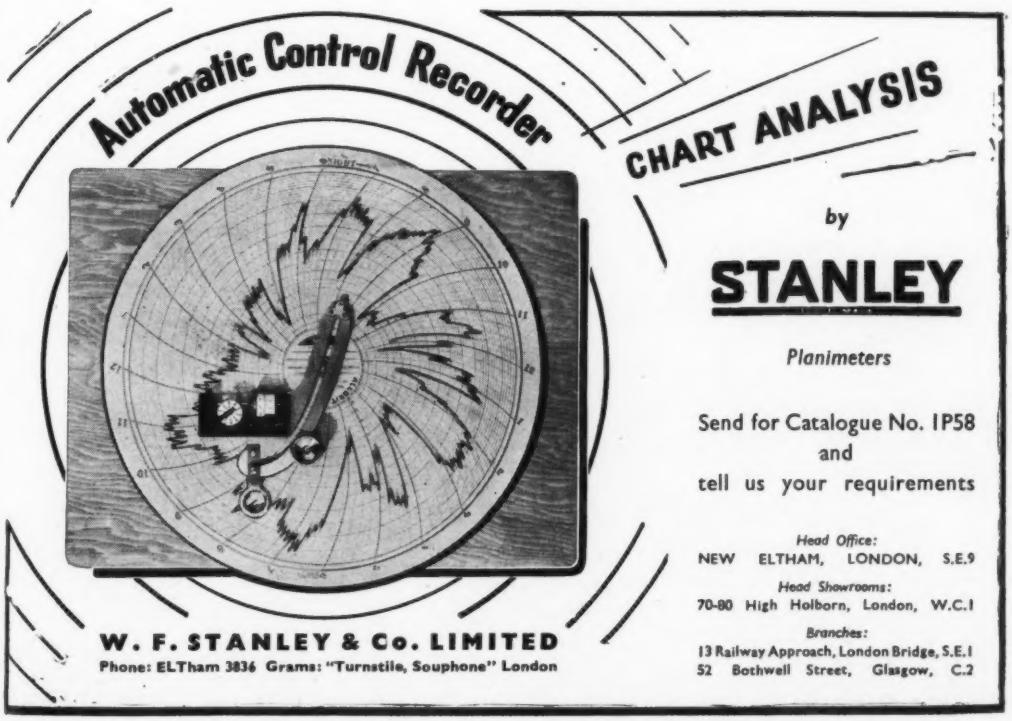
SITUATIONS WANTED – 4d. per word, minimum 6/-
SITUATIONS VACANT – 6d. per word, minimum 10/-
CAPACITIES AVAILABLE– 6d. per word, minimum 10/-
SERVICES AVAILABLE – 6d. per word, minimum 10/-
BUSINESS OPPORTUNITIES 6d. per word, minimum 10/-

Rates for other advertisements may be had on application to:

Classified Advertisement Dept.,
INSTRUMENT PRACTICE
9 Gough Square, London, E.C.4
Telephone: Fleet Street 3172

INDEX TO ADVERTISERS

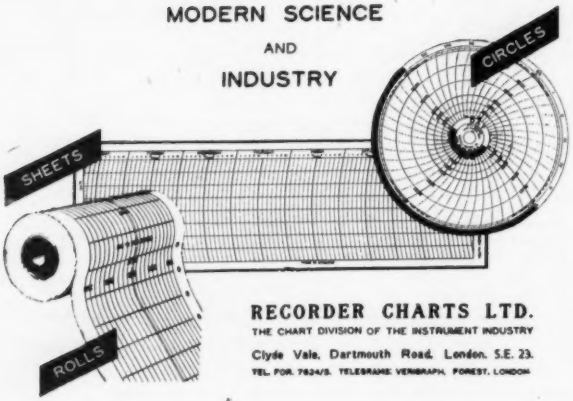
	Page
Accurate Recording Instrument Co.	982
Advance Components Ltd.	876-7, 887
Alexander Controls Ltd.	883
Arrow Electric Switches Ltd.	886
Audley Engineering Co. Ltd.	870
Avo Ltd.	889
Bailey Meters & Controls Ltd.	873
Baldwin Instrument Co. Ltd.	August
Bamford & Co. Ltd., F.	976
Barr & Stroud Ltd.	982
Beck Ltd., R. & J.	974
Bedford & Son, A. H.	August
Blackburn Electronics Ltd.	871
Blakeborough & Sons Ltd., J.	August
Bough & Co. Ltd., F. S.	August
British Rototherm Co. Ltd., The	900
British Sonceboz Co. Ltd.	Inside Front Cover
Bryans Aeroquipment Ltd.	906
Budenberg Gauge Co. Ltd.	August
Cambridge Instrument Co. Ltd.	967
Clarke & Co. (Manchester) Ltd., H.	904
Classified Advertisements	978-9
Clifford Ltd., Charles	975
Coley Thermometers Ltd.	896
Constructors John Brown Ltd.	899
Counting Instruments Ltd.	946
Darton & Co. Ltd., F.	August
Delta Technical Services Ltd.	August
Dobbie McInnes (Electronics) Ltd.	898
Drayton Regulator & Instrument Co. Ltd.	August
Elcontrol Ltd.	971
Electro-Hydraulics Ltd.	August
Electronic Components	August
Electronic Switchgear (London) Ltd.	902
Elliott-Automation Group	August
English Electric Co. Ltd., The	869
English Glass Co. Ltd., The	974
Ericsson Telephones Ltd.	903
Etcher Ltd.	878-9, 893
Evershed & Vignoles Ltd.	Front Cover
Ferranti Meters Ltd., Denis	888
Fielden Electronics Ltd.	885
Filter Co. Ltd., E. & H., The	980
Firth Cleveland Instruments Ltd.	907
Fischer Bearings Co. Ltd.	August
Fischer & Porter Ltd.	August
Foster Instrument Co. Ltd.	874
Foxboro-Yoxall Ltd.	Inside Back Cover
Gardners Radio Ltd.	880
Gas Council	Back Cover
General Electric Co. Ltd., The	950
Hendrey Relays Ltd.	898
Hilger & Watts Ltd.	August
Hoffmann Mfg. Co. Ltd., The	August
Honeywell Controls Ltd.	914
Hutcheon Duthie & Son Ltd., R.	901
Imhof Ltd., Alfred	897
Instrument Centre	974
Integra, Leeds & Northrup Ltd.	August
Johnson, Matthey & Co. Ltd.	909
Jones & Co. Ltd., Samuel	884
K.D.G. Instruments Ltd.	August
Langham Thompson Ltd., J.	912
Laurence, Scott & Electromotors Ltd.	969
Lee & Co. (Coventry) Ltd., Fred	973
Lindsey Ltd., C. S.	984
Londex Ltd.	August
Lyons Ltd., Claude	August



Circle 90 for further information

Veriyraph

RECORDING CHARTS
MEET THE MOST
EXACTING DEMANDS
OF
MODERN SCIENCE
AND
INDUSTRY



RECORDER CHARTS LTD.
THE CHART DIVISION OF THE INSTRUMENT INDUSTRY
Clyde Vale, Dartmouth Road, London, S.E. 23.
TEL. FOR. 7824/5. TELEGRAMS: VERIGRAPH, FOREST, LONDON

Circle 91 for further information

Good Instruments deserve good Cases!

Stitched Instrument Cases and Covers in leather and cloth, "made to measure", to fit your own products—also moulded to give a streamlined effect.

We design for portability, protection, speed of use and sales appeal.

Send us your problems to solve

C. S. LINDSEY LTD.

CROWN WORKS, GODMAN ROAD, PECKHAM, LONDON, S.E.15

Telephone: New Cross 4636

INDEX TO ADVERTISERS *(continued)*

	Page
Marconi Instruments Ltd.	August
Metropolitan-Vickers Electrical Co. Ltd.	August
Millett, Levens (Engravers) Ltd.	977
"Monitor" Patent Safety Devices Ltd.	976
Morris (Clerkenwell) Ltd., John	August
Murex Ltd.	971
Myford Engineering Co. Ltd.	August
Nalder Bros. & Thompson Ltd.	894
Negretti & Zambra Ltd.	August
Newall Group Sales Ltd.	August
New Western (Engineering) Ltd.	August
Norgren Ltd., C. A.	August
Oliver Pell Control Ltd.	896
Painton & Co. Ltd.	August
Penny & Giles	974
Pinder & Son Ltd., W.	August
Premier Screw & Repetition Co. Ltd.	892
Pullin & Co. Ltd., R. B.	895
Purdie & Son Ltd., E. J.	979
Pye & Co. Ltd., W. G.	908
Pyrotenax Ltd.	August
Recorder Charts Ltd.	984
Research & Control Instruments Ltd.	904
Rocol Ltd.	872
Rubert & Co. Ltd.	981
Rundle (Upper Norwood) Ltd., A.	979
Salford Electrical Instruments Ltd.	905
Sangamo Weston Ltd.	900
Savage Ltd., W. Bryan	902
Scientific Instrument Manufacturers' Association of Great Britain, The	974
Scott & Co. Ltd., A. C.	August
Scott & Co. (Electrical Engineers) Ltd., James	882
Sifam Electrical Instrument Co. Ltd.	967
Sigma Instrument Co. Ltd.	976
Simplifix Couplings Ltd.	963
Smith & Sons (Nottingham) Ltd., Sydney	August
Solartron Electronic Group Ltd., The	954
Spencer Components	976
Sperry Gyroscope Co. Ltd.	960
Stanley & Co. Ltd., W. F.	983
Stern Instruments (Great Britain) Ltd., C. T.	975
Sunvic Controls Ltd.	910-1
Swartwout Co. Ltd., The	881
Taylor Controls Ltd.	August
Taylor Electrical Instruments Ltd.	908
Telegraph Construction & Maintenance Co. Ltd., The	906
Telephone Manufacturing Co. Ltd.	875
Texas Instruments Ltd.	916
Thompson Instrument Co. Ltd., John	August
Tomey Industries Ltd.	973
Tomey & Sons, Joseph	973
Turner Electrical Instruments Ltd., Ernest	972
United Trade Press Ltd.	980, 982
Wade Couplings Ltd.	969
Walker, Crosweller & Co. Ltd.	965
Watson & Sons Ltd., W.	977
Webb's Radio	982
Westool Ltd.	890-1
Whilems Ltd., C. J.	980
Woden Transformer Co. Ltd.	981
Woodhill Engineering Co. Ltd.	974
Zeal Ltd., G. H.	August

Published by the Proprietors, United Trade Press Ltd., 9 Gough Square, Fleet Street, London, E.C.4, and printed by Herald Printing Works, York and London.
Annual subscription rate 50/-, to be sent direct to United Trade Press Ltd., 9 Gough Square, Fleet Street, London ,E.C.4, England.

ation

s!

D.
.E.15

Page
882
967
976
963
August
954
976
960
983
975
910-1
881

August
908
906
875
916
August
973
973
972

980, 982

969
965
977
983
890-1
980
981
974

August

on.